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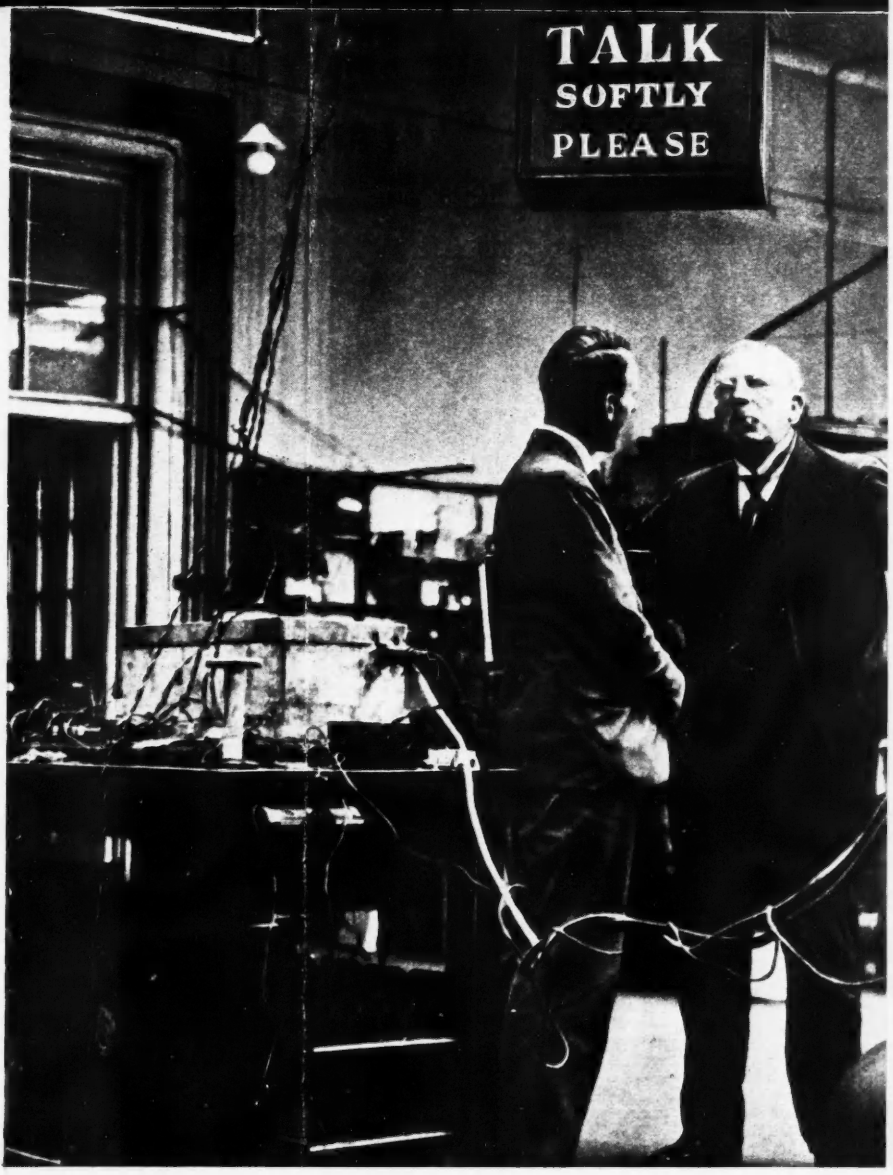

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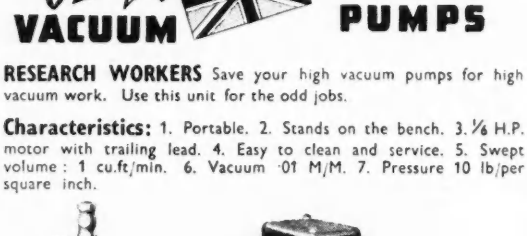

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The Progress of Science

Sulphur before Uranium

To listen to some people talk one would imagine that the atomic age had already begun. The truth is, of course, that the age when atomic power begins to make a significant difference to the world's economy is still round the corner, even though atomic explosives have brought a revolution in matters of military strategy. Confirmation of the fact that the atomic age has not yet really started is provided in the news about scarce raw materials: one finds that it is not supplies of uranium that cause concern at the present time, but the question of how to get enough of the common or garden elements like tin, aluminium, zinc and sulphur to keep pace with the needs of industries straining to expand production in order to provide the minimum essentials of civilian life and at the same time to re-arm the nations of the West. Just the same critical shortages would be evident in the economics of Russia and her satellites were the facts allowed to be known.

These shortages represent a challenge to the scientists and technologists. Let us hope that ingenuity of the same high order which is brought to the manipulation of uranium is harnessed to the problem of meeting such things as the sulphur shortage. It is a sign of the critical position with regard to sulphur that the one definite statement to emerge after the Prime Minister's talks with Mr. Truman referred to this element: Britain's stocks of this element had dropped very low, and the one immediate outcome of the discussions was the arrangement whereby the U.S.A. should send us 15,000 tons of sulphur forthwith. Rationing of sulphur in Britain was introduced on January 8 by the Board of Trade, and the U.S. Department of Commerce is restricting exports to the extent that Britain's quota for the *first quarter* of 1951—80,000 tons—is about 25% less than the comparable amount imported from America last year.

It may not be generally realised how far an industrial country like Britain is dependent on adequate supplies of sulphuric acid and, therefore, sulphur. Yet a hundred years ago Liebig stated that the prosperity of a country could be measured by the amount of sulphuric acid it consumed; it has remained a valuable index of a country's industrial activity ever since.

From 1900 to 1949 the world consumption of sulphur increased from 1¼ million tons to 9 million tons. The United Kingdom consumption at present runs around 650,000 tons a year, and of this about half is in the form of imported sulphur. The main source is the cheap Texas sulphur, mined by the Frasch process. This uses hot water which is pumped into the underground strata to melt out the sulphur deposits which are then raised to the surface by air lifts and allowed to solidify in huge vats. The known reserves of these deposits are only just over 50 million tons or about ten years' production at present rates. The United States has understandably put restrictions on further exports.

The implications for this country are serious. Some vital sections of industry are likely to go short until the gap is made up. Only one practical alternative source is available, sulphur from Sicily. At present 170,000 tons a year are produced against 560,000 tons in 1900 and only the incentive of a higher price is required to obtain the output. It means, however, higher prices for our acid and an extra economic burden.

The search for native sources of sulphur has been pursued here for many years, and more has been done than in any other country to use what is available to us. The metallurgical industry recovers the sulphur dioxide produced in roasting pyrites and zinc blende and manufactures 30% of the country's acid. (The incentive to do this was originally the requirements of the Alkali Acts to reduce air pollution in this crowded island.) In Canada and the United States a great deal of smelter gas is still wasted.

An outstanding contribution is due to I.C.I. which based the great Billingham works on the deposits of anhydrite (calcium sulphate) to be found there. By using this in a process of cement manufacture, sulphuric acid can be produced simultaneously and 6% of our production is thus made. In addition, by a process based on careful phase-rule studies by workers like Dr. F. A. Freeth, ammonium sulphate is made by reacting anhydrite with ammonium bicarbonate. Of other sources, spent oxide from gas purifying has long been used and contributes one-sixth of our production. The use of pyrites from coal refuse was developed in the war and the full exploitation of the material available might contribute 3% of requirements. Some attention will also have to be given to hydrogen sulphide in coke-oven and petroleum refinery gases which would give 10–12% of our sulphur needs.

The finding of new sources and economy in the use of sulphur are therefore pressing problems. We have previously noted the investigation of sulphate-reducing bacteria in African lakes, but this is unlikely to have any immediate practical significance. The key to economy lies in a re-examination of fertiliser production, as over 30% of our sulphuric acid goes to make ammonium sulphate or superphosphates. Of this, 10% is used only to fix ammonia in a solid form, the sulphate radicle being of no agricultural value. The acid could be saved by converting the ammonia to Nitro-Chalk or ammonium nitrate. It is also possible to apply liquefied ammonia by special sub-soil injection with great benefit, as field trials have demonstrated in the United States.

The production of soluble phosphates is a more difficult problem, although research at the Chemical Research Laboratory is going on. The obvious method is to produce triple superphosphate* by using phosphoric acid for treating phosphate rock in place of sulphuric acid. The manufacture of phosphoric acid involves the reduction of phosphates with carbon in an electric furnace to make phosphorus. The power requirements are so large that the scarcity of British electricity, let alone its price, rule this out. Yet 20% of our sulphuric acid goes to make phosphate fertilisers, and 'super' is bound to be short.

It was only to be expected that the Sulphuric Acid Control would be reinstituted and there will be some shortage and difficulty for a time, but the long-term prospects will undoubtedly take into account the availability of elemental sulphur from Italy, at a price. Italy has already announced plans to increase her output of sulphur. The transformation of our fertiliser pattern will take time and the only hope of preventing local industrial breakdowns for lack of supplies is the release of American sulphur while other arrangements are working out.

Science on the Hoardings

BRITAIN has almost grown accustomed to the dazzling new posters that first appeared on the hoardings and on buses some months ago. The colours—reds and yellows and greens—are more vivid than any of the pigments we are used to, and they have, as they were intended to do, arrested everyone's attention. The liveliness of colour is reflected in the trade names given to these new printing inks: these are Neon Red, Fire Orange, Saturn Green, Signal Yellow.

The extra fire of the colours is achieved by making use of the phenomenon of fluorescence, and it is this fact that has interested scientists, especially chemists doing research on pigments. For until the appearance of the fluorescent posters there was no knowledge that anyone had succeeded in making a pigment that would not only produce fluorescence under the stimulation of daylight but would also then glow with the same colour, or very nearly the same colour, as the natural colour exhibited by the pigment under conditions when it shows no fluorescence.

Fluorescence in itself has long been known and has been intensively investigated in the past twenty years; some of the results of the investigations have been applied, and can be seen on our television screens, and on the many signs which glow brightly in the dark. Fluorescence is the phenomenon shown when a substance emits visible light under the impact of radiation. (It is akin to phosphorescence, but this name is restricted to cases where the glow persists for a long time after the exciting radiation has ceased; phosphorescence and fluorescence are both covered by the term *luminescence*.) A characteristic of the fluorescence is that the wavelength of the light emitted is *longer* than that of the light causing it. This means that the exciting radiation (i.e. the radiation striking the material) can itself be invisible ultra-violet radiation with a wavelength shorter than that of the light at the violet end of the visible spectrum, while the resulting light can lie within the visible range. This sort of fluorescence is the one most familiar to us.

The needs of war, followed by the demands of television, intensified the search for newer and better luminescent materials, technically known as phosphors. In the past five years alone more than *seventy* British patents have been accepted in connexion with luminescence. The older phosphors were inorganic materials such as calcium tungstate and the old familiar barium platino-cyanide used for many years on X-ray screens. They are still in extensive use.

A number of organic substances were also known to fluoresce—quinine sulphate for example, and paraffin oil, the fluorescence of which are well known. Intensive research in the past decade has produced many more organic phosphors, such as that known forbiddingly as zinc 8-hydroxyquinoline, used in crayons for writing wartime signs intended to be visible in the dark under ultra-violet light.

But despite all the work done, nobody succeeded in producing one that could be made into a satisfactory pigment for the printing industry. Most solid phosphors are pallid and insipid in appearance in ordinary light, and need energetic excitation by X-rays or high-speed electrons or ultra-violet radiation from a mercury-vapour lamp before they glow with any life. (Everyone knows the pale and sickly look of the paint used on watches with luminous dials.) Moreover they were too coarse for ink, and many of them were unstable. Their daylight colour had not necessarily any resemblance to the colour of the fluorescent light they emitted. Organic dyes, on the other hand, were often colourful in themselves, but it was difficult to produce them in a form suitable for a paint or pigment, that is to say, in the form of a powder insoluble in the medium used as a binder and fixative. Attempts to use them for display purposes just as dyes were failures, for they lost their colouring ability far too quickly. These two difficulties have now been overcome by the inventors of Day-Glo, the

* Apparently one needs to guard against the possibility, the rather faint possibility, that sulphur deficiency might occur as a result of using this triple superphosphate instead of ordinary superphosphate. The official summary of the Australian C.S.I.R.O. annual report (1949-50), just published, includes this passage:

"A new mineral deficiency, that of sulphur, has been discovered affecting soils in the Southern Tableland region of New South Wales. Work with superphosphate has shown that the sulphur content of this fertiliser plays an important part on soils of very different origin within this region. Neither element alone is fully effective. Thus phosphatic fertilisers such as triple superphosphate which contains no sulphur would be ineffective in the development of these sulphur deficient soils. Sulphur is particularly needed for protein formation in the plants, and has a marked influence on nitrogen fixation by clover."

In ordinary soils there is no lack of sulphur compounds, and sulphur deficiency is likely to remain a rare plant 'disease' even in areas where triple superphosphate is largely used.

trade name under which the now familiar poster inks were brought out.

The advantages of a pigment that fluoresces in the right way in daylight can be appreciated only if the mechanism of colour-appearance is understood. A coloured substance is seen to be coloured because, when irradiated by white light, it subtracts some of the energy from it and reflects the rest. The coloured surface must therefore of necessity give out less energy than the light shining on it. The actual colour seen depends on where in the spectrum the substance does most subtracting. If it subtracts mostly the violet and blue and green and, then reflects the rest, it will appear an orange-red. The word 'subtraction' itself shows that the process involves a reduction in light energy. In fact, a pigment reflecting as little as 60% in the red part of the spectrum, and nothing elsewhere would be called a very pure 'bright' red. This situation is changed enormously if a red pigment can make use of the absorbed energy at the blue end of the spectrum, or in the invisible ultra-violet beyond it, and transform this into fluorescent light *that is also red*. The 60% just mentioned can then become as much as 120% or 130% (according to the Day-Glo inventors). In other words, the pigment fluorescing in daylight is giving out more energy in the red part of the spectrum than is actually *in* the incident white light. This is precisely the effect attained with the new fluorescent inks.

It is to be supposed that many chemists are energetically searching for a way of producing such fluorescent pigments now that it has been shown to be practicable, and doubtless there will be new varieties. In fact, J. Waddington & Co. applied for a British patent for such inks in September 1950, and their chief chemist has given some facts about a fluorescent printing ink—called Brillink—that can be used in much thinner deposits than is practicable with Day-Glo, and yet be completely fast to light.

But full credit must be given to two Americans from Cleveland, Ohio, as the pioneer inventors of the Day-Glo inks. They are Joseph L. Switzer and Robert C. Switzer. The key patent would appear to be the U.S. patent No. 2498592 granted to them in February 1950. In the patent specification the inventors described their method, which is basically very simple. They take a fluorescent organic dye, dissolve it in a solution of a transparent thermosetting plastic, and then 'polymerise' the coloured resin—that is, heat it until it turns solid because its molecules have joined together in complex multiples. This glass-hard coloured and transparent solid is then ground until it is a powder. This powder is the pigment which is incorporated in the printing ink. Many transparent resins are suitable for making the pigment, the only conditions necessary being that (i) the resin must be thermosetting and (ii) it must not react chemically with the dissolved dye. The reason for using a thermosetting resin is that if a thermoplastic one were used, the heat generated in grinding would render it gummy and so make it impossible to produce a fine powder. The chemistry of the process is probably one of fixing the dye molecules in the interstices of the resin molecular network in such a way that they are much more stable, and do not lose their properties as rapidly as when in ordinary liquid solution: in effect they are protected against outside influences just as a fly can be preserved in amber. The new inks do not last indefinitely; their life varies from three to six weeks or more according to the amount of direct sunlight they receive. In the subdued light of our winter they last longer than in the summer; in positions where they never receive direct sunlight they last longer than in places exposed to the sun's rays.

Inks made from these daylight-fluorescent pigments seem even more vivid by contrast with ordinary inks when the sky is overcast. This is because the water drops in the layers of cloud are too big to cause scattering, and so the sunlight passing through them suffers only normal absorption. With water there is more absorption of light at the red end of the spectrum than at the other end. So light that comes through the cloud layer, though diminished in energy compared with the sunlight that enters it, is

Maleic Hydrazide may cause Mutations

WE have received the following letter from Dr. P. C. Koller of the Chester Beatty Research Institute, and in view of the serious implications it carries, we feel that it deserves prominence in "The Progress of Science":

"I read with interest the article 'Maleic Hydrazide' in your December 1950 issue. It is another example amongst the many we have, which show the great interest in the attempts being made to control diverse phenomena in Nature. We already possess an impressive array of chemicals to kill viruses, bacteria and insects, to eradicate weeds, and to promote the growth of seedlings. Now Maleic Hydrazide is here to retard the blossoming of fruit trees, to suppress the sprouting of stored onions, carrots, etc. Many of us no doubt will be proud of these achievements, which all testify to our increasing conquest of Nature.

But we should not forget to ponder about the repercussions which any interference with Nature may bring in its wake. Reading the article—the enthusiasm of which is to be applauded—I failed to find any reference to the possible hazards which might be involved in using the drug on plants on a large scale. (Maleic Hydrazide is already being marketed in America under the name of 'Barsprout'; *Science*, 1950, 112, p. 597.) But how much do we know about the genetic effect of this particular drug? The facts of genetics as we now know them do not allow us to consider only the immediate effects and advantages of using it; we must also study the hereditary implications, before embarking on any large-scale project for regulating plant development by the application of Maleic Hydrazide."

Yours faithfully,

P. C. KOLLER.

Chester Beatty Research Institute, London S.W.3.

We understand that experiments already carried out show that it is a mutagenic substance—i.e. it produces mutations; other research workers are suggesting that it might possibly also act as a carcinogen.—Editor.

relatively richer in ultra-violet, to which water is very transparent. The result is that ordinary pigments are dulled by the diminution of visible light while the fluorescent pigments shine with their usual vividness. At dusk and dawn this contrast is still more enhanced because of the richness of the daylight in ultra-violet at these times.

The pigment powder produced according to the Switzer patent is actually dull to look at. It has to be dispersed in a suitable medium for brushing or printing and applied in layers of the correct thickness to show its qualities. The medium used must have a refractive index of about the same value as that of the resin in which the dye is dissolved. Even when suitably dispersed the pigment is still dull when seen in bulk, and results depend on the choice of a suitable method of applying it to paper. The Switzers worked on this aspect, and found that there were two conditions for the best results. First, the actual concentration of the dye in the resin had to be very small indeed in order to exhibit the most fluorescence. Bigger concentrations caused absorption of the activating radiation and its wastage through conversion into heat. Secondly, the coverage of surface had to be fairly heavy in order to produce sufficient 'body' of colour. Because of this second condition, fluorescent pigments of the Day-Glo type have to be applied *thickly*, the average layer being some three thousandths of an inch thick, whereas with normal printing ink a thickness of no more than half a thousandth of an inch is obtained. This great thickness of ink cannot be applied by the methods of printing used in book and magazine production. The method most used with Day-Glo inks is that of silk-screen printing, which in effect consists of printing with a stencil in which parts not to be printed are obscured by paper, or some other material, held on silk, through the meshes of which the ink is squeezed by rollers. This is not the only way of applying the fluorescent inks for with suitable thinners they can be sprayed or brushed, but it has been found that the thinning necessary for these processes produces its own troubles.

Mechanically these inks suffer in the same way as others from weathering, so a thick layer is again indicated. Even so, some of them run in heavy rain and leave an unattractive residue that has lost its fluorescent richness. The resin used is transparent; so is the dispersing medium. Consequently much light gets through to the surface underneath. This must therefore be as white as possible and have a diffusing surface.

Some of the conditions mentioned are controlled by the patentees and makers in America, and British users import the luminescent pigments. Other conditions are controlled by the ink-makers here, who issue the inks under licence only to people who observe certain rules of usage. When all the conditions are observed, the result is a type of display of arresting brilliance, visible at 200 yards under circumstances when normal inks are virtually invisible even at 50 yards. Without doubt a new chapter has begun in the application of science to advertising display.

The NPL's Calculator

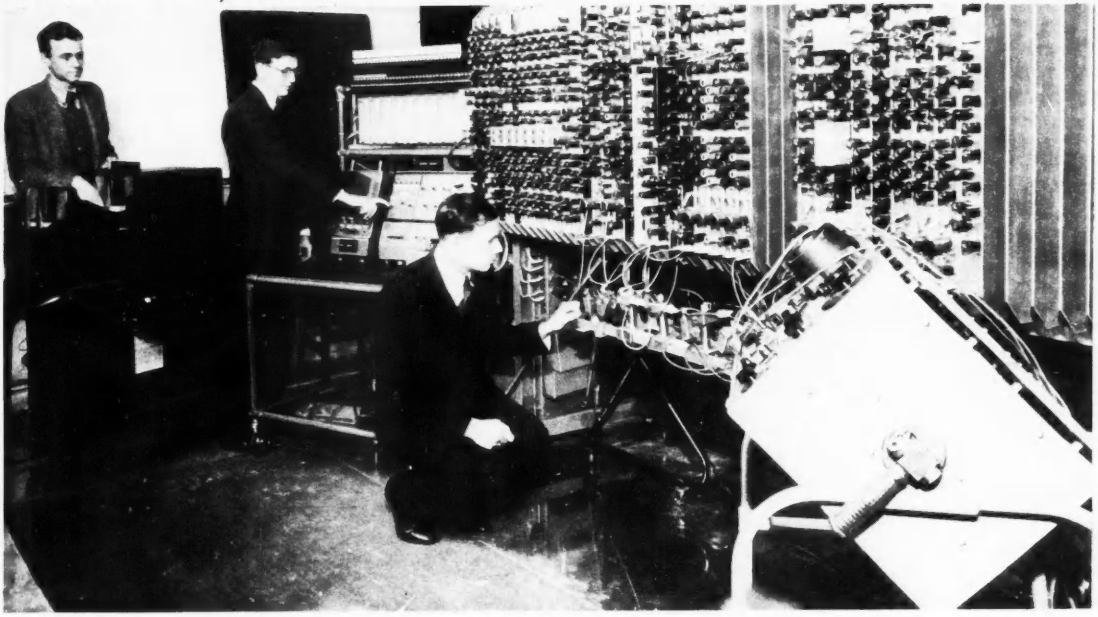
THE pilot model of a new 'Automatic Computing Engine' known for short as ACE* was recently demonstrated at the National Physical Laboratory. Professor Hartree, Britain's best-known authority on such matters, has divided calculating devices into *instruments* and *machines*; the former are the sort in which numbers to be computed are changed into measurements of physical quantities (such as voltage), whereas the latter operate directly with numbers as digits, a simple example being the familiar adding machine. On this definition ACE is a calculating machine, and it is automatic, extremely fast, and universal in the sort of calculation that can be carried out.

The speed is obtained by means of thermionic valves and electronic circuits, in which, of course, messages travel with the speed of light, so that the machine can operate immeasurably faster than is possible with the human brain. Within the machine the numbers are used on what is called a *binary scale*. That is to say, a number is divided into powers of two. Thus a number such as 35, which means 3 tens and 5 units, on the binary scale would be 101001, meaning $1+2+2^5$, the 0's representing the absence of $2, 2^2$, and 2^4. The fact that $1+1=2$ indicates how such a binary scale can express any number whatever as a succession of 1's and 0's. This enables the designers to arrange for electrical pulses to indicate 1's and the absence of electrical pulses to indicate 0's. (To handle calculations in the familiar decimal system, the machine is capable of translating this into binary form at the beginning and turning it back into decimal form at the end.)

Any addition of numbers usually involves the memorising of steps in the calculation. For instance, anyone adding 18 to 29 says to himself first: "9 and 8 make 17; put down 7 and carry 1." If the 7 is not written down it has to be remembered, and so has the 1 to be carried. In ACE, therefore, an important part of the apparatus has to store numbers reached in earlier stages, and be made to pass them on at the right time. In popular language this has been called the 'memory' of the machine, but it is better thought of as 'storage' if we are to remember that ACE remains a machine, and can only perform operations for which instructions are injected at the beginning. The storage is achieved by closed circuits in which the pulses go on circulating until required. (In ACE part of each such loop is a column of mercury in which the electrical pulses have been transmuted into ultrasonic pulses in order to slow them down and save space—an electrical pulse travelling at 186,000 miles a second would need a loop of 186 miles in circumference for a time of a thousandth of a second.)

The injecting of the instructions into the machine involves elaborate 'programming' beforehand. This is the most skilled part of the whole computation, and can be done only by suitably trained operators, usually mathematicians. The programming involves the breaking-down of a complicated calculation into stages of addition and subtraction, and also allowance for 'storage' and release of information at the right time. The programme is coded on a number of Hollerith cards on which the code is shown by the number and position of punched holes, these holes providing gaps through which electrical contacts can be made to get the correct train of events into operation. These contacts are in a section of the machine that can be called the 'control', corresponding in a human being to the brain that decides the nature and time of an arithmetical operation. ACE has numbers of lights on its control panel

* The name is a tribute to Charles Babbage, who planned a 'computer engine' a century ago.



The model calculator at the National Physical Laboratory.

to give signals of what is happening, and a buzzer is incorporated to provide a signal for specific purposes. For example, the machine can be programmed to discover if a number is prime. The machine does this by dividing by 3, 5, etc. to discover if there is a remainder. At the end of the sequence, the buzzer sounds if the number is in fact a prime one. (Alternatively, the buzzer could be arranged to sound if the number were not a prime one.) ACE takes three seconds to perform this operation for a six-digit number.

The machine can be divided into four parts: input control, arithmetical calculator, storage, and output. There are intercommunications between the control and the storage and calculator to allow backward and forward traffic. The output is delivered on punched Hollerith cards. A surprising fact for the layman is that, though the machine has 800 valves in forty vertical racks (a much smaller number than that used for the more restricted American machine known as ENIAC), only one of these racks is involved in the actual counting, the basic arithmetical operations so to speak. This arithmetic is a process of adding or subtracting. It is easy enough to see that multiplication for a human calculator, if the old multiplication table is not used, can be done by successive additions. For example, 8×9 can be found by adding up nine sets of eight. It is not quite so easy to see that division can also be broken down into a process of subtraction, but it can. Thus 29 divided by 8 can be done by subtracting 8 once, giving the quotient 1, then again, giving the quotient 2, then again, giving the quotient 3 and a remainder 5. Very many complicated formulae can be thus broken down in addition or subtraction, and such processes are the basic ones of the arithmetical counter in ACE. Even with this apparently awkward and, so to speak, retrogressive way of doing arithmetic, the speed of ACE is very high indeed. It is not easy for the imagination to grasp what this speed really means. A month's manual calculation could be done in a minute by ACE. Another illustration is afforded by the number of digits that it will handle—nearly a thousand million in about fifteen minutes. What this number of figures means can be seen from the fact that paper calculation involving them would take up half a million foolscap sheets and make a pile as high as Nelson's Column.

In science and industry there frequently arise problems that need a great deal of routine arithmetic in their solution, and it is in connexion with problems of this sort that a computer like ACE is very useful. The purpose of this pilot model is to give the designers opportunities of trying it on numbers of problems in order to foresee necessary modifications, and in this process consultations with industry will be encouraged. One typical problem handled by this model—which although it is called a pilot model is a complete computer that cost £50,000 to design and build—is that of calculating the behaviour of a new lens system. In the ordinary way, every ray striking each face of the system has to be calculated separately, using Snell's law of refraction and the trigonometry of triangles. This may take a team of calculators months to do, and at the end a slight change may have to be made in the design of the lens system and the whole procedure repeated, with the possibility of further repeats until a satisfactory result is obtained. ACE does one set of such computations for twenty rays in one plane in about ten minutes.

It must be stressed that the 'programming' takes a long time. So the speed of action of the machine is much less for a single calculation than the human brain could achieve; it really is speedier to multiply 2 by 4 in one's head than to get an operator to programme it, code it, operate it, and decode the answer. It is therefore in the realm of continued, complicated, and tedious calculation that the machine comes into its own.

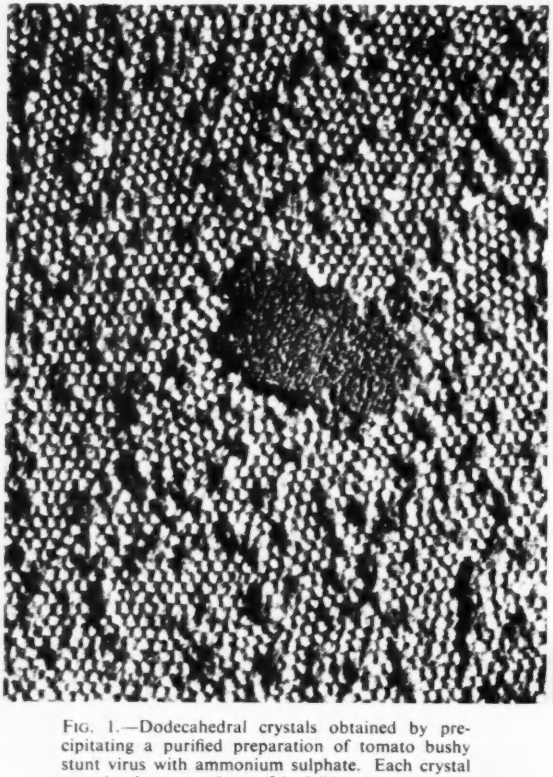


FIG. 1.—Dodecahedral crystals obtained by precipitating a purified preparation of tomato bushy stunt virus with ammonium sulphate. Each crystal contains large numbers of invisible virus particles. × 180.

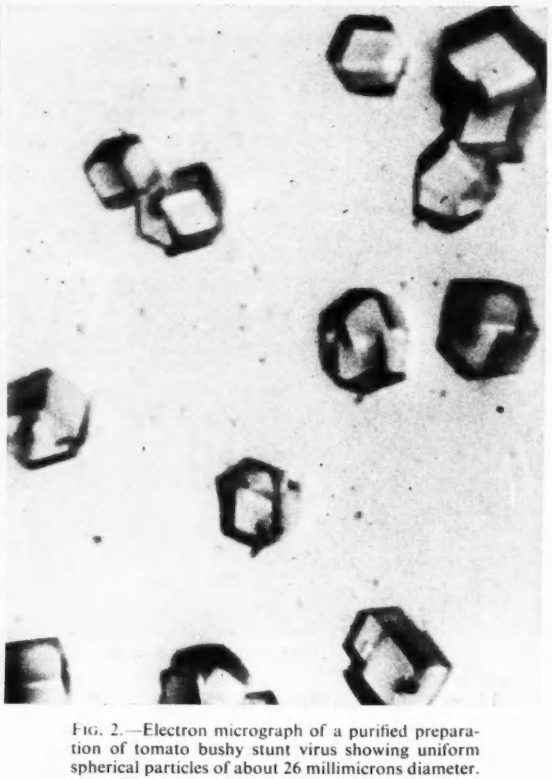


FIG. 2.—Electron micrograph of a purified preparation of tomato bushy stunt virus showing uniform spherical particles of about 26 millimicrons diameter. (A millimicron is a millionth of a millimetre.) Preparation shadowed with palladium. × 40,000.

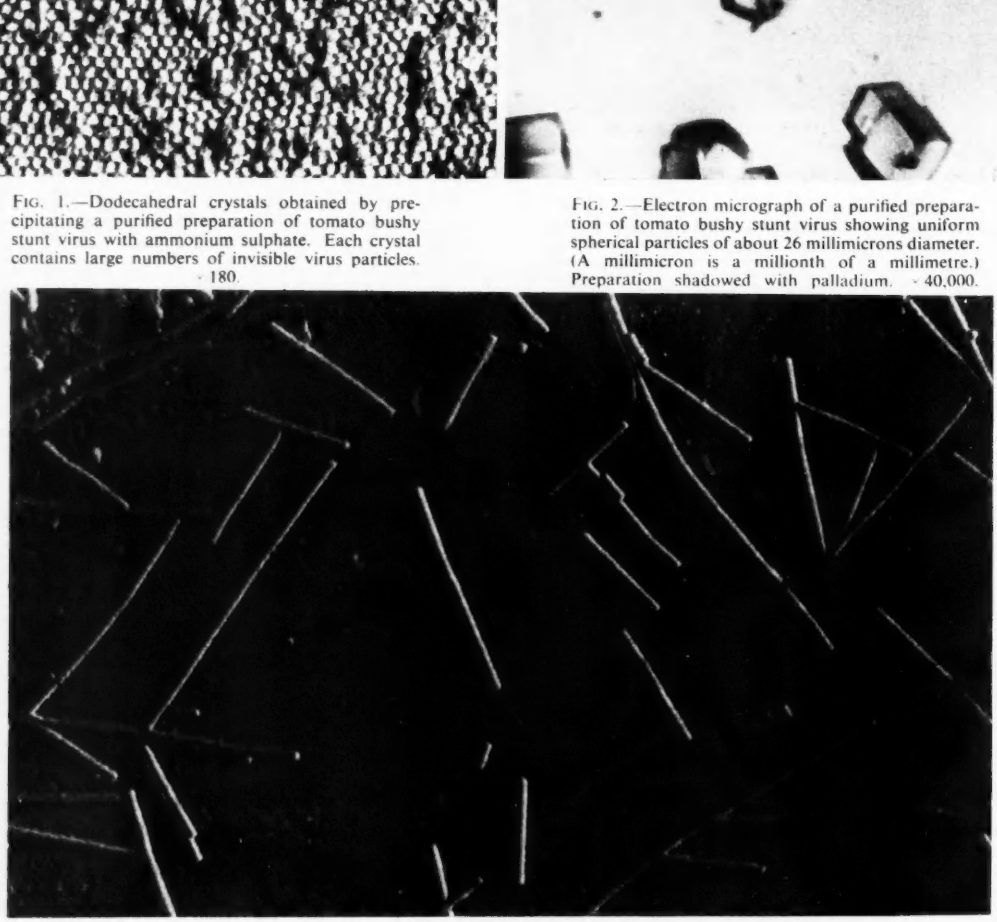


FIG. 3.—Electron micrograph of a purified preparation of tobacco mosaic virus showing rod-shaped particles of various lengths but uniform width of 15 millimicrons. Preparation shadowed with palladium. × 80,000.

(Photos: Rothamsted Experimental Station).

Viruses: Molecules or Organisms?

F. C. BAWDEN, M.A., F.R.S.

Deputy Director of Rothamsted Experimental Station

INFLUENZA, infantile paralysis, measles, foot-and-mouth disease, infectious chloroses ('yellows') and the degenerative diseases of plants, are only a few of the diseases caused by viruses, but they suffice to show that their economic importance would alone be more than enough to ensure that they commanded the attention of pathologists. Particularly is this true today, when the relative importance of viruses becomes increasingly greater as effective remedies are discovered against more and more of the troublesome diseases caused by bacteria and fungi, whereas the virus diseases remain stubbornly intractable.

But viruses attract attention for other than practical reasons. Ever since they were first discovered, about sixty years ago, they have excited interest and provoked controversy, even in branches of science that are not usually concerned with pathology. This fact has a simple explanation; viruses do not fit comfortably into any of the major categories recognised by the systematists, and their evolutionary significance and status are uncertain.

The controversies about them have mainly centred on the questions *Are they living?* and *Where do they come from?* Some workers have answered these questions in no uncertain manner, but as often as not, the answers provided by different workers have been contradictory. The conflict of opinion is obvious in much modern writing on viruses; sometimes the viruses are called organisms, sometimes they are called molecules, depending on the preference of the individual writer. The only factual answer to the two questions is to say *No one knows*. Although this is admittedly unsatisfying, I do not propose to attempt any other answer, but to outline the reasons why the questions cannot be answered with certainty. This task is probably best approached by considering for a few moments what is meant by the term 'virus diseases' and how they came to be discovered.

The literal translation of the Latin word *virus* is 'poison', but scientists have rarely used it in this sense. Until the second half of the nineteenth century it was a general name to cover the causes of all kinds of diseases, whether infectious or not. When Pasteur destroyed the general belief in the spontaneous generation of life and established the germ theory of disease, it became a synonym for 'germ' or 'microbe'. At that time it was confidently thought that, for each disease, there would be a specific visible microbe, which could be isolated and grown on artificial culture media. This belief was rudely shaken in the eighteen-nineties, when it was shown that the causes of mosaic disease of tobacco plants and foot-and-mouth disease of cattle were present in seemingly sterile fluids that had been passed through filters capable of stopping all bacteria. Since that discovery, the term 'virus', as used by scientists, has become restricted to pathogens of this type, that is to say, to pathogens that are too small to be resolved by ordinary microscopy or to be retained by bacteria-proof filters.

Ability to cause disease and their small size relative to other pathogens are two characteristics of viruses. Another seems to be obligate parasitism,* for although there have been occasional claims that viruses have been made to multiply on the kinds of artificial media that support the growth of most bacteria, none of these has been confirmed. The significance of this criterion is uncertain, for failure to multiply except in living cells may simply mean that the right artificial medium to support multiplication has not yet been found. Nevertheless, the fact that there is no established example of a virus multiplying in a lifeless medium does provide a striking contrast to bacteria.

In living cells, on the other hand, they multiply with great rapidity; during the time it takes a bacterium to become two, a virus that attacks the bacterium may increase by more than a hundred-fold. When viruses multiply, most of the progeny resemble the parent type, but variants with new characters occasionally arise. If a new variant is preferentially favoured by a change in the environment, then it will predominate over the parent type and the culture will thus show signs of adaptation. The ability to multiply, to vary and to be adaptable to changes in circumstances are all phenomena that are widely considered to be characteristic of living systems. All these phenomena are observable with viruses, so that it is small wonder that most workers in the past assumed them to be the simplest type of living organisms.

Estimates of the sizes of virus particles were early made from experiments in which suspensions were passed through filters with pores of different sizes and finding what size of pore retained the particles. These estimates suggested that individual viruses had particles of a characteristic size, and that the sizes of different viruses ranged from particles that were only a little smaller than some undisputed organisms down to particles only a little larger than some proteins which are usually described as inanimate molecules. This size range has been confirmed by later work with the electron microscope and the ultra-centrifuge, which permit more precise measurements of sizes. Almost inevitably, as viruses seem to bridge the gap between living and non-living systems in size, they have been postulated as bridging it in other respects as well.

They have been represented as transitional stages between molecules and organisms, though different writers have expressed different opinions about their evolutionary significance. Sometimes they have been regarded as 'upward' stages in the evolution of life, although the view that they resemble or derive from the forms in which life first originated, fits ill with the fact that they behave like obligate parasites. Inability to multiply except inside other living cells is hardly a property that would have favoured the perpetuation of the first forms of life. More often they are represented as having derived from larger organisms by a process of degeneration. This is more plausible. It is known that bacteria sometimes lose the ability to synthesise substances that are essential for their growth, and, if cultures are continually supplied with such substances

* An obligate parasite is an organism that is tied to a parasitic existence.

ready-made, they may come to depend on this external supply. From this fact, it can logically be argued that viruses are descendants from larger pathogenic organisms; as a consequence of being always in the cells of other organisms, where they are provided with most or all of their essential needs ready synthesised, they have lost more and more of the functions and structures they no longer needed. On this theory, viruses with particles of different sizes would be organisms that have degenerated to different extents, the larger ones having lost fewer of their initial structures and functions than the smaller ones.

A less remote relationship with visible organisms than a protracted evolution by progressive degeneration has been postulated by various workers at different times. Usually the virus has been described as an invisible stage in the life-history of a larger organism, the postulated organism being the peculiar bodies that are regularly found in the cells of plants and animals when they are suffering from certain virus diseases. The precise nature of these bodies is still uncertain, but all the evidence points to their being precipitates or aggregates of virus particles in quantities sufficient to produce microscopically visible structures. Certainly many of these bodies are composed largely of virus particles, and the formation of some can be simulated by precipitating a virus in the test-tube by various methods. The bodies have a structure unlike that of any known type of organism and those occurring in different virus diseases differ widely from one another, some being crystalline and others not.

Occasionally the transformation of viruses into organisms in the laboratory has been claimed. A recent claim of this type has been made by Dr. G. M. Boshyan and his colleagues at the Russian All-Union Institute for Experimental Veterinary Medicine. According to an article in *Soviet Union* (August 1950), they have "arrived at the conclusion that viruses and bacteria are akin in nature, turn into each other and are merely different forms of existence of one and the same micro-organism". It is too soon to comment on this claim, but it is fair to say that, should it be confirmed it will be the first of its kind that has, and would certainly entail the modification of current ideas. The Russian workers not only state that certain viruses, including the one associated with infectious anaemia of horses, multiply in artificial nutrient media, and can develop into bacterial cells of various forms and sizes, but also that the viruses withstand boiling for forty minutes, and then heating twice in an autoclave at a temperature of 120° C. Previously, tobacco mosaic virus has been outstanding for its resistance to heat, but it is inactivated in 10 minutes at 90° C., and most others have been found to be inactivated by heating to much lower temperatures.

Too little is known about the constitution of most viruses to permit any useful discussion about their possible relationships with micro-organisms. A good deal is known, however, about several that attack plants, and it seems highly improbable that these are alternative forms of micro-organisms or could change into them. As different viruses have particles of different sizes, they may also differ in their constitution, and it would be premature to generalise from these plant viruses, though evidence is accumulating that they are not exceptional. From plants infected separately with several plant viruses, specific nucleoproteins have been isolated in a seemingly pure chemical state; at least the isolated proteins pass all the customary physico-chemical tests for homogeneity. These protein preparations are infective at high dilutions, and there is every reason for identifying these nucleoproteins with the viruses themselves. They differ fundamentally from even the simplest micro-organism; they can be crystallised without losing their infectivity, but although this is a spectacular feature, it may mean little except that all the particles are, within narrow limits, the same size. The differences go further than this. The simplest bacterium contains a wide variety of complex components, including nucleoproteins, and its composition is subject to continual change. By contrast, these viruses are nucleoproteins, and the nucleic acid and protein of which they are composed are united to give particles with a fixed regular structure. In their chemical simplicity and internal structure these viruses have a closer resemblance to some of the complex substances synthesised by organisms than to whole organisms or cells.

When studied in the laboratory these purified virus preparations appear totally inert, and there is nothing in their behaviour that separates them specifically from preparations of other nucleoproteins. Only their ability to infect and multiply in susceptible cells does this, and infectivity is a property that is easily lost. Some treatments —irradiation with ultra-violet light is one—destroy infectivity without producing any other changes that have yet been detected. Obviously some fundamental change has occurred, because a virus has been turned into an inactive protein, but current physico-chemical techniques are too insensitive to detect it. This point is not raised simply to demonstrate the limitations of these techniques when applied to biological problems, although this is worth stressing. It is raised rather to show that, although differences between bacteria and viruses may be many and large, differences between viruses and non-infective proteins may be few and subtle. At present the only way to distinguish between the two is to see whether or not they will infect and multiply in susceptible cells. Only when they are present in other systems that are indisputably alive do viruses show any of the phenomena that are customarily associated with life. It is this fact that prevents any positive answer to the question *Are viruses living?* because there is no method of distinguishing between what properties belong specifically to the viruses themselves and what to the whole infected cell.

It used to be assumed that the question would become answerable when the nature of viruses was known, but the assumption was wrongly based. It postulated that there was some specific criterion of life and that viruses were unique in raising such a question, but this is far from true. Biological systems do not divide neatly into those that are unquestionably living or not. Everyday objects as diverse as dogs and kennels raise no problems, for everyone appreciates the broad manifestations of life. But difficulties immediately arise if an organism is taken to pieces and the status of each piece is questioned. Is every organ, tissue and cell that make up a dog alive? If so, are all the many complex units within each cell alive? If not, which are and which are not? There are no valid criteria on which objective decisions can be made, and conclusions about the status of many of the components of living systems can only reflect personal opinions and preferences. An

unequivocal demonstration that a virus had been transformed into a micro-organism would be a major event, but it would not justify a claim that 'life' had thereby been created. Such a claim would simply mean that a worker had decided arbitrarily to consider one phase as living and the other not; to do so would mean going beyond the scope of experimental science and entering the realms of metaphysics.

The lack of objective criteria for making decisions about the status of border-line systems is largely responsible for the continuance of the controversies about viruses. The views of individual workers are inevitably influenced by their approach. As causes of disease, there is little in the behaviour of viruses that differs from the behaviour of bacteria, and pathologists are apt to call them organisms; physicists and chemists who study purified virus preparations find little difference from the behaviour of inert substances that they call molecules. At first sight the gap between these two views seems too wide to be bridged, but it is largely false, and has come from a misuse of words; to call them one or the other goes much further than present knowledge permits and prejudges what is still an open question.

A colourless word such as 'particle', which does not carry the philosophical or scientific implications of 'organism' and 'molecule', is better suited to their uncertain status. The word 'organism' is fully applicable only to biological systems that have independent functions which are clearly distinguishable from those of other living organisms; the word 'molecule' is appropriate only for substances whose exact chemical constitution can be determined; it implies a reproducibility of structure that cannot be demonstrated with particles as large as viruses. In this viruses are not unique, for all kinds of living cells contain a variety of complex components that does not fit into either of these extreme categories. Some of these, such as chromosomes and mitochondria, are structures large enough to be seen with ordinary light microscopes, whereas others, such as the cytoplasmic nucleoproteins and proteins, are invisible and approximate in size to virus particles. Some also resemble viruses in appearing to be self-reproducing. At present the relationship between viruses and such components of normal cells can only be a subject for speculation, but their similarities seem greater than those between viruses and micro-organisms. When tobacco mosaic virus increases in a leaf, there is a corresponding decrease in normal proteins, suggesting that infection diverts cell metabolism into new channels that end in the synthesis of virus instead of the normal products. Thus, from current knowledge, the non-infectious nucleoproteins seem the closest analogues of viruses, and among them may lie clues to the origin of our now troublesome viruses.

MICHURIN: A COLOUR FILM FROM RUSSIA

Just before Christmas the Scala Theatre, London, was packed from floor to roof for a single showing of a full-length Russian colour film, the story of Ivan Vladimirovich Michurin. The merits of the film lay in sound acting and very competent colour work. The defects were a script of monumental dullness, an utter lack of story rhythm, and cutting so wanting in imagination that Pudovkin and Eisenstein would have felt physical agony.

Both in Western Europe and America, films have taken so many liberties with the facts of history that it would be foolish to challenge a Russian film on this score. Still, *Michurin* is obviously designed as instructional and semi-documentary, and great care has been taken to gather authentic detail for the background. Its departures from fact are not the wild improvisations of a Hollywood writer faced with the task of enlivening history; they are carefully calculated.

Perhaps the fairest way to present the matter is first to tell the story of the film as a Russian student would see it, and then to review it briefly from the Western point of view.

It is summer in old Russia. A ramshackle conveyance rattles down a lane to deposit at the gate to a modest garden a bloated American capitalist—fairly pleasantly bloated: it is not overdone—and his interpreter. They enter, and a tall shabby figure, stooping over the flower beds, takes their bags and directs them towards the house. They ask to see the great Michurin. The gardener introduces himself.

Interpreter and capitalist vie in apology. Michurin's fame as a horticulturist has reached the United States; they have travelled halfway across the earth to see his garden. So he shows it to them, pointing out that Nature is malleable, that once you know the secret, you can blend one plant with another. The American's reaction is to break out into enthusiastic praises and to offer Michurin a blank cheque to come to the States and work there. American money will indeed transport his whole garden across the ocean. He has only to say the word.

The word Michurin says is "No". He will work in Russia and for Russia. That is final.

Meanwhile a robed figure at one and the same time fatuous, genial, and sinister (no small feat that, but the caste are all good actors) has been peering over the garden hedge. He is a priest, who has brought Michurin a clock to mend. They fall into talk and he upbraids the gardener for tampering with nature. Michurin, with the righteous wrath of science, sends the priest about his business. There is a nice scene too in which a youngster robbing the orchard is not beaten but given the apple he came to steal. But not much really happens until the Revolution, of which Michurin is a keen supporter. Then it turns out that the young orchard robber has become a Red Guard, and has arranged for the orchard to be state-supported.

Michurin is old and alone—his wife's death, shown in a long and not very moving sequence, occurred because the bourgeois doctor was too busy to come to her. Yet despite age and loneliness, Michurin gathers his energies to serve Russia. He has plans for new fruits, new grain, a botanic world. But still the professors deride him. Filled with the theories of the priest Mendel, they do not believe that Michurin can make the new frost-resisting fruits he promises. The news of Lenin's death comes just when the heavy snows are putting Michurin's orchards to a savage test.

Kalinin, president of the Soviets, comes to see him in a lurid sunset, and in an endless series of sequences youths and maidens present him with flowers and vegetables, and tell him of the triumphs his theories have won in the far north and in the East.

Now for the facts, as we know them in the West. Michurin was a vague, rather mystical, gardener with 'green fingers'. He hated, and probably failed to understand, the precision of the Mendelian theories, preferring to talk of plants as though they were children to be moulded by instruction in his flower-bed classrooms. Though he bred some interesting new varieties, to portray him as the father of modern Russian agriculture is a wild flight of fancy. But that is how the official agro-biologists today acclaim him. This they do under the direction of Trofim Lysenko, who, a few years ago seized control of Russian biology, removing the classic biologists by every sort of intimidation. Lysenko, who appeals to Michurin as the originator of a Marxist biology more powerful to change the face of nature than the priest-derived Mendelism of the West, has triumphed completely. This film is part of the campaign of consolidation, not the attack.

This is, in short, a film that must tax the endurance of all but the sternest of the faithful. Its dullness is not an accident: the same forces which now paralyse Russian science paralyse the camera.

CLIFFORD TROKE.

Giant Frogs and

The experimental production of giant plants by 'shock treatment' of the reproductive cells has been known for 25 years. Exposure to low temperatures, X-rays and chemical agents may cause odd 'sports' to arise with one or more extra sets of chromosomes—such forms are called polyploids. These individuals are sometimes giant forms which can be propagated vegetatively to produce new giant varieties.

Polyploidy also occurs naturally in plants; and the selection of such polyploids by observant plant breeders has given rise to many modern varieties which have larger flowers or larger fruits.

The most effective of the artificial 'mutagenic' agents is colchicine—an alkaloid extracted from the autumn crocus (*Colchicum autumnale*).

Experiments to produce giant animals by colchicine treatment failed until 1948 when Professor Gösta Haggqvist of the Karolinska Institute in Stockholm exposed eggs of the common frog to a weak colchicine solution at the moment of fertilisation. The tadpoles which developed from these eggs were giants (see photograph No. 1) but so malformed that they died before metamorphosing into frogs.

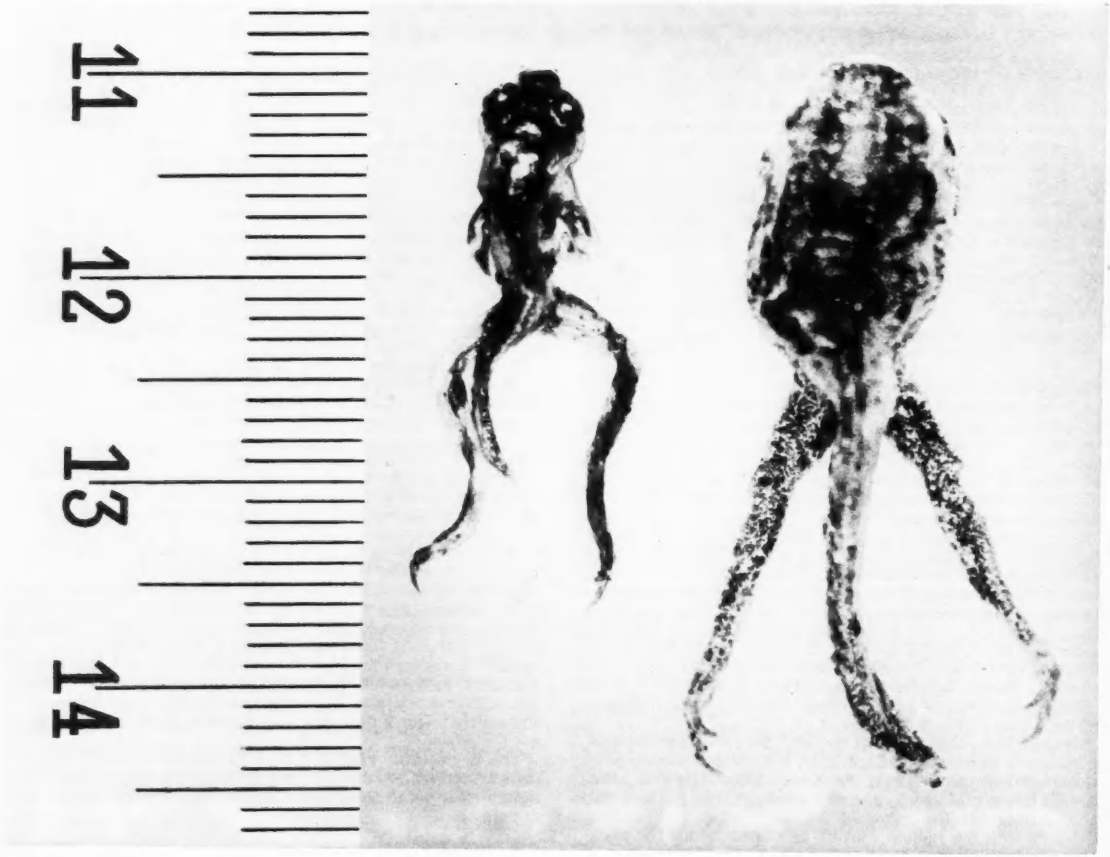
More recently Haggqvist, assisted by Dr. Allan Bane, has applied the colchicine technique to rabbits. Semen from a buck with the normal number of chromosomes—i.e. two sets of 22 chromosomes per body cell—was mixed with colchicine and used to fertilise the eggs of a normal doe. Seven young were born after a normal gestation. Two of these proved to be triploids, i.e. individuals with three sets of 22 chromosomes in each body cell instead of the normal 44.

The tentative diagnosis of triploidy was first made on the evidence of the abnormally large red blood cells of these rabbits. It was later confirmed by chromosome counts carried out by an independent investigator, Yngve Melander at Lund University (see photograph No. 2).

Apparently the colchicine had affected the eggs from which these rabbits developed, influencing one of the cell divisions in each case so that an extra set of chromosomes was retained.

The triploid rabbits grew considerably more rapidly than their parents. The triploid female passed its mother's weight at the age of three and a half months. As the third photograph shows, these rabbits ended up a good deal larger than the normal 'diploid' type.

Professor Haggqvist is now trying to produce triploid pigs and poultry by the same method. He thinks that giant fast-growing farm animals might make more economic use of feeding-stuffs than normal types.



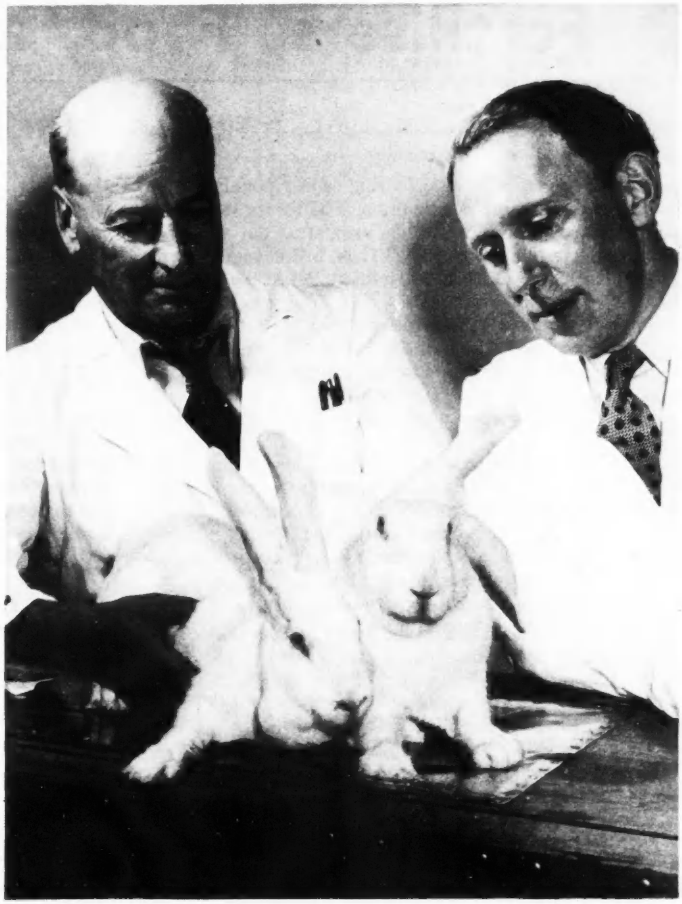
Rabbits

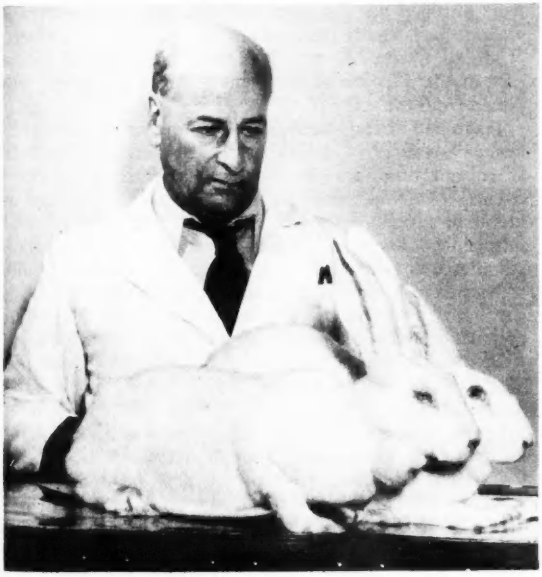
(*Opposite page*) Two frog tadpoles of the same age. The specimen on the right is from an egg treated with colchicine. The other is from a normal egg. The scale is in centimetres.

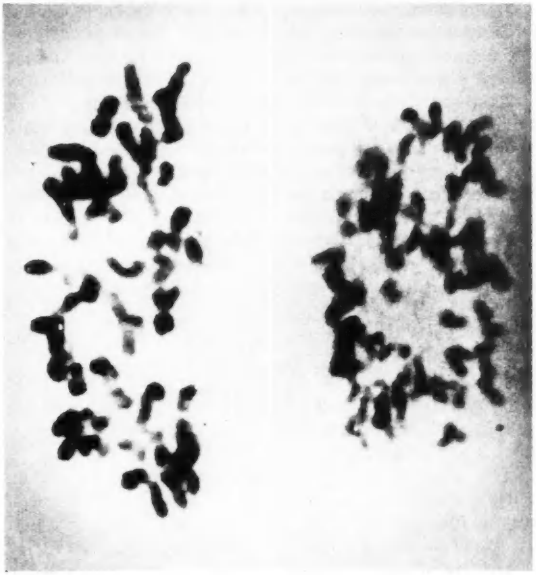
(*Right*) Professor Gosta Haggqvist (left) and Dr. Allan Bane compare a giant rabbit (right) with a normal control specimen. The giant arose as a result of colchicine treatment of the egg from which it developed.

(*Below left*) The giant rabbit is twice the weight of the normal 'control', which is nearer the camera.

(*Below right*) A cell from a triploid rabbit (right) showing 66 chromosomes instead of the 44 found in the normal rabbit's cells (left).







Fertilisers, Food, and People

D. P. HOPKINS, B.Sc., F.R.I.C.

It is now generally recognised that world population is increasing at an unprecedented rate. Figures for the world population can only be rough estimates, but they do indicate the trend of expansion. Thus, in 150 years before 1800 the increase was about 350 million, but in the next 150 years it has been 1400 million.

A further analysis of the figures shows how the world's population pressure has intensified during the present century. In 1900 the estimate was roughly 1600 million; thus between 1800 and 1900, the increase was about 700 million; the same numerical increase obtained in the period 1900 to 1950.

There is no reason to suppose that this accelerating rate of expansion will ease, and we should anticipate a total world population of at least 3000 million *before* the turn of this century—that is to say, during the lifetime of most of the younger readers of this article. The huge problem of meeting the requirements of all these people from the world's resources is not some distant problem for future generations; it is the most urgent problem of our own times.

Food cannot be mined from accumulated reserves. It is the product of soil and labour. We need not worry unduly about the supply of labour to produce food for the future world population, for there will clearly be no shortage of people. The factor limiting the increase of the output of the world's farms will be the amount of food-producing soil available. At present, the world has 4 billion acres of food-producing soil for more than 2 billion people. But it is altogether misleading to translate that statement and say that this is equivalent to 2 acres per person. National and geographical boundaries produce a medley of widely differing acreage/population ratios, while the biggest areas of productive soil do not coincide with the areas carrying the biggest populations. These and other reasons make a scientific distribution of the world's food neither politically nor economically possible. Nor are all the 4 billion acres what we should call good soils; quite a high proportion are much poorer than the soils that we now regard as 'marginal' in Britain, and millions of acres are sick and damaged soils that have been cropped to exhaustion in the past hundred years.

Once the world has recognised the problem of feeding its people, a great deal can be done to increase the quantity of food that the world produces. One of the most hopeful methods, though certainly not the only one, rests on an increased use of fertilisers. In many countries this has increased output per acre, yet even in such countries fertilisers have been far from fully exploited. On a large proportion of the world's existing farmland, fertilisers are not used at all, or are used at such low rates that their effects are insignificant.

The idea that crop yields can be increased by adding various substances to the soil is not modern. The use of animal manures, lime, and marl is older than Christianity. In recent centuries a variety of substances has been tried —salt, soot, bones, blood, etc.—but it was not until the nineteenth century that this adventitious exploration was scientifically directed. This stemmed from the intervention into agriculture of two great chemists—Sir Humphry Davy and Liebig. By 1840 Liebig had been able to build up the so-called mineral theory of plant nutrition, later to be improved on in detail by plant physiologists. He demonstrated that plants acquired their carbon from the carbon dioxide of the air, and that their requirements from soils were simple mineral elements such as potassium, phosphorus, calcium and magnesium, to be found by analysis in their bodies.* The natural productivity of soils, and the usefulness of added substances, depended upon the quantities of these elements they contained. The modern fertiliser industry began almost immediately after Liebig had published this theory. John Bennet Lawes (who later started the Rothamsted Experimental Station) was the first maker of 'superphosphate', and in 1843 he opened the world's first 'artificial manure' factory—at Deptford, in London. His superphosphate was quickly successful, so much so that a shortage of bones from which he made it restricted production. In 1845 he turned from bones to mineral forms of calcium phosphate, such as coprolites which could be surface-mined in Suffolk and Surrey. Later, mineral phosphates for the purpose were imported.

While Lawes was building his superphosphate business he was also conducting field and plot tests with fertilisers on the farm of his Rothamsted estate, out of which grew the now world-famous Rothamsted Experimental Station. The research work he initiated was not confined to the use of superphosphate. Although Liebig had stated that the nitrogen requirements of plants were, like their carbon requirements, obtained from the air, Lawes believed that their nitrogen derived from the soil. The argument was violent, but finally Lawes and his colleague, Gilbert, produced irrefutable experimental proof that the major part of the nitrogen requirement of most plants was obtained from the soil.

There had already been casual experience of the usefulness as 'manures' of mineral nitrates, imported from Chile. It had not, however, been realised that much of the effectiveness of animal manures and such animal residues as blood or ground hoof and horn had been due to their nitrogen content, but when this was discovered a great stimulus was given to the use of nitrogen-containing substances as fertilisers. Waste ammoniacal liquors from the gas industry were used, but their variability and frequently damaging effects on plants (due to toxic impurities) led to their development in the form of sulphate of ammonia. The annual importation of South American nitrates increased rapidly.

In the eighties, basic slag, another important phosphatic fertiliser, was introduced. The Thomas-Gilchrist process for steel manufacture gave rise to a by-product slag in which most of the phosphorus in the original iron ore was

* It must be understood that the presence of a particular element in plant ash (the analyst works on the ash not the living plant) does not prove that the element is essential to plant growth.

contained. For a few years the slag heaps piled up. Field experiments then showed that this slag, if very finely ground, was an effective supplier of phosphorus to crops.

At about the same time, though more slowly than was the case with other fertilisers, the benefits of potassic fertilisers were recognised; and increasing tonnages of potash from the German mines were used by farmers.

The so-called artificial fertilisers, then, are substances that supply, principally, the three dominant nutrients, nitrogen, phosphorus, and potassium which tend to be deficient in cropped soils. (A number of other nutrients are required in small quantities). In practice, a fertiliser must fulfil one important economic criterion; it must not be dear—that is to say, the dressing required to produce an extra weight of crop must not cost more than the money value of the additional yield.

Many people suppose that fertilisers have come into increasing use only because supplies of animal manures have diminished with the mechanisation of farms, and that cropping rates were much better in the supposedly good old days of 'muck'. Sir William Ogg, the present Director of Rothamsted, has made some interesting comparisons of yields at different periods, which are summarised in the table below:

	Yields per acre			
	Wheat	*Bushels Oats*	*Barley*	*Tons Potatoes*
1. 1771	24	38	32	—
2. 1793–1815	21	35½	32¼	—
3. 1885–1894	29½	40½	33	6
4. 1936–1945	34½	47	38	7
5. Average yields at Rothamsted Farm, 1936–1945	50	73	55	9

The small discrepancies between 1 and 2 need not be regarded as a drop in productivity between 1771 and 1793–1815; the first line of figures was not drawn from the whole country. It is the closeness of these two sets of yield figures that matters, not their differences; they both indicate the cropping level of the pre-fertiliser period. On the other hand, it is unfair to credit fertilisers with more than a part of the increased yields shown in the table; other advances in agricultural science, notably that due to the plant breeder, also helped. It is in the striking differences of 4 and 5 that the effect of fertilisers is most clearly shown. At the Rothamsted Station Farm about as much phosphate and potash are applied annually as are used on the average arable acre in British farming, but twice as much nitrogen; the yields obtained at Rothamsted of wheats, oats, barley, and potatoes are 44, 55, 45, and 30% respectively higher than the average yield for Britain's farmlands as a whole.

The country which has so far made the best use of fertilisers is Holland, where for many years between the wars rates of application per acre were more than double those of any other country except Belgium. Did the Dutch farmers produce bigger crops as a result?

	Yield of wheat in (cwt. per acre) National average, 1930–34	*Average use of fertilisers per arable acre at same period (cwt. per acre)*			
		Sulphate of ammonia or equivalent	*Superphosphate or equivalent*	*Potash*	*Total*
Holland	23·0	2·5	4·5	1·3	8·3
Britain	17·8	0·4	1·3	0·1	1·8

Nor need the Anglo-Dutch comparison be confined to arable farming. On Dutch grassland the average use of sulphate of ammonia per acre is 2 cwt.; in Britain it is between 0·1 and 0·2 cwt. Dutch farmers carry twice as many cattle per acre as British farmers, and the average milk yield per cow per lactation there exceeds 800 gallons, while that of British cows is around 500 gallons. The climate of Holland is fairly similar to that of Eastern England. With much of their land below sea-level and other under controlled drainage, Dutch farmers may have a special advantage in moisture retention at dry periods. But conditions are sufficiently similar for this comparison to be regarded as a rough judgment of the effects of two different national levels of fertiliser use. It should be added here that our own use of fertilisers in *arable* farming has doubled since the war; but even now we are still a good way behind the pre-war Dutch level.

Experiments at the Jealott's Hill Research Station measured the effects of fertiliser treatment upon grass. Grass is a difficult crop to measure, for its yield is not obtained at a single time of maturity and harvest; it is a continuously productive crop. Here are the figures for 1930:

	Crop weighs expressed as dry matter in pounds per acre		
	Spring yield	*Late summer or autumn yield*	*Total*
Without N fertiliser	3180	1764	4944
With N fertiliser	4429	3316	7745

Moreover the output of grass protein per acre when fertiliser had been applied was 246 lb. as against 122 lb. per acre without fertiliser. Thus, although the treatment increased the crop yield by 75%, it actually increased the protein content by just over 100%.

In the United States much information has been accumulated to show similar gains in output per acre by the use of fertilisers. The United States possesses the biggest fertiliser industry in the world, but its size reflects her vast acreage of farmland rather than a high general rate of application. It is sometimes suggested that the 'dust-bowls' of America were the result of continuous cropping

methods made possible by the use of fertilisers, which produced the crops while not replacing the humus. This is a completely false idea. As Dr. E. M. Crowther has pointed out, in Kansas, Colorado, and Oklahoma, where erosion was severe, the average consumption of fertilisers was approximately 1 cwt. of sulphate of ammonia, 15 cwt. of superphosphate, and less than ½ cwt. of muriate of potash per 1000 acres. In fact, the major cause of 'dust-bowl' erosion was a lack of fertilisers rather than the reverse. The soils became exhausted so that no protective cover of vegetation could grow. Today in guarding against further erosion and renovating past damage, one of the principal methods of the U.S. Soil Conservation Service is the use of fertilisers to enable cover-crops to be grown.

If in the U.S.A. fertilisers are still used at lower rates than in Europe, what of South America, that other great food-producing region of the 'New World'? Here the average use of fertilisers is so much smaller than that of North America that it can be described as negligible.

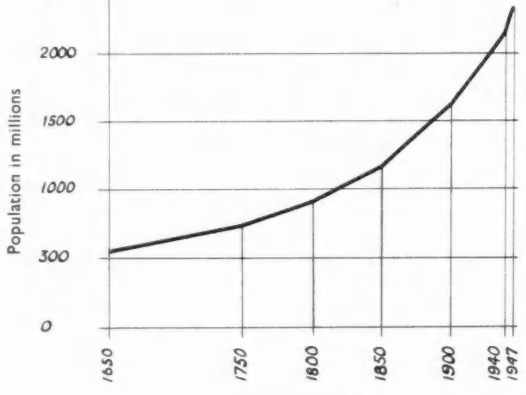
Nevertheless, it must not be assumed that fertiliser practices which have proved successful in Western Europe can be applied directly to countries in different continents and with different climatic conditions. For each environment, for each regional soil type, and for each crop, the most effective fertilisers and methods of application must be found. Thus, in Australia, it is only on the wetter fringes of the great wheat belt that nitrogenous fertilisers have been effective in increasing crops. At Adelaide with a 16-inch rainfall in the growing season a small dressing will raise the yield by 12 bushels an acre; at Rutherglen, with only 13 inches of rainfall, an even bigger increase has been shown. But away from these wetter fringes the response of the wheat belt to nitrogen is "little or nothing". But phosphatic fertilisers are essential; the increases in crops after superphosphate has been applied are frequently more spectacular in Australia than in other parts of the world. It is a widespread practice in Australian wheat farming to build up nitrogen in the soil by growing subterranean clovers (which, being leguminous, fix nitrogen from the air), using superphosphate to encourage this 'pioneer' crop.

Asia's Need of Fertilisers

In Asia rice, not wheat, is the supremely important crop. But rice is grown in swamps and our Western methods of fertiliser application fail in the paddy fields of the East. Although rice production is greatly increased by nitrogen applications, soluble nitrogen compounds are invariably washed away quickly. Japanese workers found that sulphate of ammonia applied on the surface of paddy fields was oxidised to nitrate and then largely lost because this was washed away; but if sulphate of ammonia is pushed down to a lower level in the mud bed, where conditions favour reduction and not oxidation, it accumulates there until required by the growing crop. If this advance could be applied to all the rice fields of Asia, how many extra handfuls of rice per head per day could be produced?

The introduction of fertilisers into what is commonly a primitive and peasant agriculture is an operation largely dependent on education, politics and economics: science scarcely enters into this matter. It must take many years before any appreciable progress can be made. Probably the most hopeful method is for governments to set up small experimental and demonstration farms in various centres; indeed, in India such farms have already convinced local farmers of the efficacy of simple modern techniques. Pioneer farms of this nature would also be bases for investigating the particular soil needs of their localities.

Enough has been said to show that a fuller use of fertilisers could raise levels of food production all over the world. There are two somewhat different tasks for scientists, administrators, and politicians: (*a*) to encourage higher levels of application where fertilisers are already well accepted, e.g. Britain, the U.S.A., and (*b*) to introduce a general use of fertilisers where as yet they are scarcely used at all, e.g. India, China. As world population and world demands for food increase, necessity is bound to become the compelling force for these expansions. But food production (especially when it requires a revolution of methods), is a long-term operation. It is courting disaster to wait until widespread food shortage is a truly imminent threat.



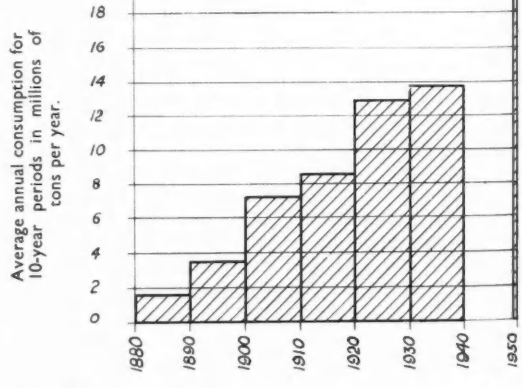


FIG. 1 (*left*).—The growth of the world's population. Fig. 2 (*right*).—The increase in world consumption of superphosphate, a valuable index to the expansion of artificial fertiliser usage.

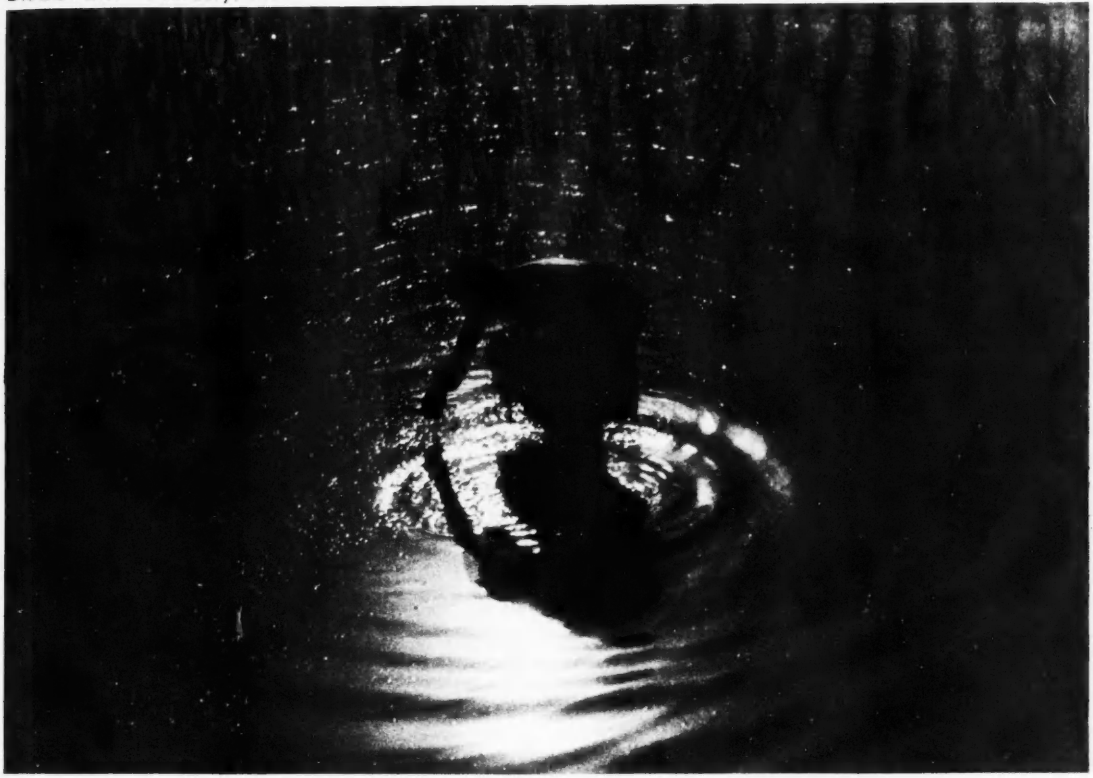


FIG. 3.—Rice-growing in the East is a primitive operation, and the output of this commodity can be much increased by more extensive use of artificial fertilisers. In Russia this has led to trebling of the average yield per acre, it is claimed.
(BRITISH OFFICIAL PHOTOGRAPH of a Malayan paddy field)

Could the necessary amounts of fertiliser be manufactured? The already known deposits of phosphates and potash could meet the strain of expanded demand for several centuries. Nitrogen is present in unlimited quantity —in the air. The development during World War I of an industrial process to 'fix' the air's nitrogen (i.e. to make it combine with oxygen or hydrogen to form simple compounds) still in my opinion, eclipses all other achievements of nineteenth- or twentieth-century science. The quantity of nitrogenous fertilisers (and their specific kind, whether sulphate of ammonia, liquid ammonia, ammonium cyanamide, ammonium nitrate, urea, etc.), is solely determined by the world's will to devote capital and labour for building the necessary factories.

In countries where fertiliser effectiveness is already recognised, the crucial influence in expansion is economic. It is the farmer who decides how much is used, because it is more or less true (even in these days of subsidies) to say that it is the farmer who pays the bill. In the latest FAO report on fertilisers it was emphasised that this influence was again becoming dominant for the first time since 1940; from 1940 to 1949 it has been the tonnage of fertilisers produced that has determined the tonnage used. When farmers begin to feel uncertain about the prices they are likely to receive for their next harvests, they also feel uncertain about the size of their fertiliser programmes. A tendency to reduce fertiliser consumption has been intensified by rises in fertiliser prices, due in some countries to the removal or reduction of fertiliser subsidies. However, as world population increases and the demand for food intensifies, economic obstacles of this kind will be swept away.

Is there any other scientific idea which is over a century old yet which still offers more to the future than it has given in the past? It is true to say that so far the world has merely scratched the surface of fertiliser possibilities. Even if the 4 billion acres of the world's agricultural land cannot be increased, no one can predict their maximum food output with fertilisers applied to the fullest extent.

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The Colombo Plan, recently published by H.M. Stationery Office, pays considerable attention to the need to increase farm productivity in the East, and stresses the need for more artificial fertilisers.

Foucault's Pendulum: A Centenary Note

ANGUS ARMITAGE, M.Sc., Ph.D.

THE risings and settings of the sun, moon, and stars were originally explained by supposing the entire universe to revolve daily about the Earth, which was assigned a stationary situation in the midst. However, about four hundred years ago astronomers began to attribute these phenomena to a daily rotation of the Earth about its polar axis. This view of the matter eventually established itself after generations of controversy between the supporters of the two rival theories. One of the ways in which it was sought to decide the question at issue was to devise some crucial mechanical experiment which would give a different result according as the Earth did or did not rotate.

Already in the sixteenth century, when the principles of mechanics were still in dispute, natural philosophers began to ask what effect a rotation of the Earth would have upon the apparent line of descent of a freely falling body, say, of a stone dropped from the top of a tower. Some authorities thought that the stone would lag behind the eastward-spinning Earth and would appear to fall to the west of the tower; others held that the stone would share the Earth's motion and would show no deviation from the vertical. Eventually Newton gave reasons for expecting an *eastward* deflection of the falling stone. Subsequent experiments have, upon the whole, borne out his prediction, although the effect to be sought is generally minute compared with the errors of observation (because the highest available tower is still of neglible height compared with the Earth's radius).

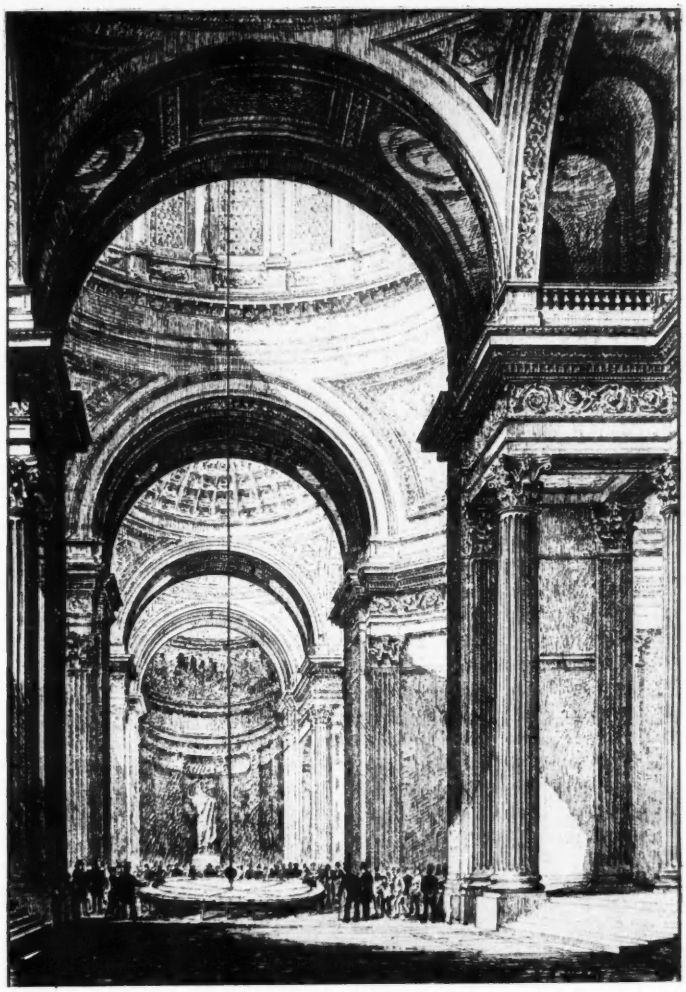
Another consequence to be expected from the rotation of the Earth is that a projectile fired horizontally in a northerly or southerly direction should in general appear to be deflected to one side or the other of the target at which it is aimed. For the eastward speed of the Earth's surface decreases progressively from the equator towards the pole. Hence a projectile, fired northwards in our latitudes and partaking of the diurnal motion of its place of projection, must gain on the corresponding motion of the target and show an eastward deflection, while, if fired southwards, it must lag behind the target and deviate to the west. In either case, the deflection is to the right; in the southern hemisphere it would be to the left. In the eighteenth century George Hadley showed the bearing of this principle upon the characteristic bias shown by the north-east and south-east trade winds of the tropical belt, and by the south-westerly winds of our temperate zone; it also determines the directions of air-flow in cyclones and anticyclones. As a factor affecting the course of a projectile the phenomenon is, in practice, almost imperceptible.

However, a century ago the French physicist Foucault devised a simple experiment which he conceived as a means of rendering visible the *accumulated* deviations of a projectile discharged backwards and forwards along its trajectory, and thus of demonstrating the diurnal motion of the Earth. He described his first successful trials in a short communication to the French Academy of Sciences dated February 3, 1851.

Jean-Bernard-Léon Foucault was born in 1819 in Paris, where his outwardly uneventful life was spent. As a boy he showed exceptional skill in the construction of mechanical toys, but his health was delicate and his talents were not of the kind to shine forth brilliantly at school and college. Only when his interest had been focused upon some specified problem could he bring himself to acquire the technical information needed for its solution, so that, as J. L. F. Bertrand remarked, "the story of his studies is that of his discoveries". In later life he would surprise his friends with requests for enlightenment upon some point or other of schoolroom science, of which he would then proceed to make a new and brilliant application. Beginning his career as a medical student, Foucault eventually obtained an appointment as a scientific officer in the more congenial surroundings of the Paris Observatory. His researches covered many branches of pure and applied physics, and he received in his lifetime numerous honours including the Copley Medal of the Royal Society. He is noted particularly for his determination of the velocity of light (see DISCOVERY, Jan. 1951, pp. 1–3), which he showed to be greater in air than in water, a result interpreted as establishing the wave theory as against the corpuscular theory of light. While still at the height of his powers, however, Foucault was stricken with an obscure paralytic disease which caused his untimely death in 1868.

In his classic experiment which we have now to consider, Foucault set a simple pendulum swinging in a well-defined plane of oscillation and established that this plane showed an apparent rotation about the vertical, relatively to the surrounding objects, which could be interpreted as a direct consequence of the diurnal rotation of the Earth. In his analysis of the phenomenon, Foucault considered first the behaviour of such a pendulum suspended vertically above the north terrestrial pole; it was clear that its plane of oscillation would remain fixed in space (relatively, say, to the stars) owing to the inertia of the bob and to the absence of any forces tending to displace it from that plane. If one noted the line in which the plane of oscillation intersected the ground at a given instant, then, supposing the Earth to rotate from west to east once in twenty-four hours, this line should appear to swing round, relatively to terrestrial objects, at the same rate as the Earth, but in the opposite sense. More complicated conditions prevail, however, when the experiment is tried in some arbitrarily chosen latitude, say at Paris, where it was first carried out. For at the pole the vertical retains a constant direction throughout the experiment; but elsewhere it daily describes a cone in space. However, Foucault showed that a rule could be established for predicting the rate at which the direction of motion of the pendulum bob would seem to change relative to its immediate neighbourhood on the earth's surface.

Foucault obtained his first positive result with a pendulum consisting of a brass bob of 5 kilograms weight supported by a steel wire only two metres long, hanging from the roof of the cellar under his house in the Rue d'Assas. He would start a trial by drawing the bob aside from its position of equilibrium and securing it by means of a loop of vegetable fibre until all its lateral oscillations had been damped down; then the fibre was burned through



The first spectacular demonstration of Foucault's Pendulum was given at the Pantheon in Paris. A similar pendulum can be seen in motion every day at the Science Museum at South Kensington.

and the pendulum began vibrating in an exact plane. The suspending wire should strictly have been attached to some support unaffected by the Earth's rotation; but Foucault found that, if certain precautions were taken, failure to satisfy this condition did not vitiate the results. The experiment was repeated upon a larger scale at the Observatory; but the most spectacular demonstration took place in the Panthéon from the dome of which a spherical bob of lead cased in copper, weighing 28 kilograms, was suspended by a steel wire 67 metres long. A pin projecting downwards from the bob impinged, at each extremity of the arc of swing, upon a cake of moist sand, making a channel in it. The plane of oscillation as recorded by this means was found to revolve at a rate which would have taken it through 360° in about 32 hours. This agreed quite well with the movement predicted, for the latitude of Paris, by his previously established rule.

When the experiment was repeated at the Exhibition of 1855, Foucault introduced an ingenious electromagnetic contrivance for maintaining the oscillations of his pendulum for hours by impulses periodically administered. In the meantime he had hit upon an alternative device for demonstrating the rotation of the Earth. This was the *gyroscope*, a massive flywheel pivoting freely about its centre of gravity; when set in rapid rotation its axis of spin indicated a fixed direction in space.

Foucault's pendulum experiment awakened much interest; it was repeated in many quarters, and it formed the subject of numerous commentaries linking it up with mechanical principles previously established. Since the advent of Relativity the phenomenon has, indeed, been robbed of much of the significance that it held for Foucault and his contemporaries. The old argument as to whether the Earth rotates daily in a stationary universe or remains fixed in a rotating one cannot now be related to any real distinction in nature. What the experiment is actually held to reveal is a rotation of the Earth relative to a plane fixed in the 'local inertial frame', which is another matter. However that may be, Foucault's Pendulum will always represent, in the phrase of Prof. René Dugas, "one of the essential conquests of mechanics".

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FIG. 1.—The Sea Stickleback busy building his nest. The weed in his mouth is a few moments later stuffed in on top of the nest.

FIG. 2 (*left*).—The fish is coming out and up from the bottom of the nest after having passed through it with his thread from top to bottom. FIG. 3 (*right*).—Carrying the thread round the nest.

The Mating of the Sea Stickleback

P. SEVENSTER

PARENTAL care, which plays such an essential part in the life-cycle of many higher vertebrates, is absent in most fishes. They lay their eggs somewhere in the tremendous water-spaces and leave the survival of the eggs almost entirely to chance. To compensate the risks of this manner of reproduction they have to lay an enormous number of eggs. There are, however, quite a few exceptions and the sticklebacks are among the most surprising. In Europe the family is represented by three species, all of which show elaborate, almost bird-like reproductive behaviour and, incidentally, lay comparatively few eggs. Such highly specialised behaviour has not failed to attract the attention of biologists, and the three-spined stickleback, common in fresh water and easily kept even in small tanks, became a favourite object for the study of animal behaviour. Now it is perhaps one of the most striking discoveries in this field, that many features of animal behaviour are strictly innate and are as characteristic of a given species as any morphological feature, so that it is possible to compare such features in one species with those in a related one, exactly as the anatomist compares the bones of different species. Along these lines, the evolution of movement or even of behaviour systems as a whole can be traced.

Such an approach has proved extremely fertile, and it seemed worthwhile to explore the relatives of the three-spined stickleback with this aim in mind. The ten-spined stickleback has been studied for some years now and recently the Marine Biological Laboratory at Plymouth offered an opportunity of initiating research on the Sea Stickleback, which is the only real sea fish among them. Next to nothing is known about its life-history in nature, but much can be deduced from observations in sea-water aquaria, in which natural conditions are imitated as closely as possible. It has been found, for example, that they do not form schools as do the other sticklebacks, nor do they react to each other's movements. Feeding in one individual does not stimulate feeding or hunting in another, unless the actual prey is in sight. We may, therefore, conclude that normally they live on their own.

In spring, however, this situation changes. The males then settle down in the coastal areas and become hostile to one another. At first the fighting is more or less at random, but remarkably soon boundaries are established, each fish occupying a separate territory. From then on the size or strength of the individuals has little to do with the outcome of their combats. If a male enters a neighbour's territory, he is immediately attacked by the owner and as a rule he then flees instantly. If, however, a victorious male pursues the intruder into the latter's territory, he in his turn will retreat as soon as the second male turns round and stands his ground. How a stickleback behaves when it encounters another stickleback is influenced by its experience of previous encounters: after a while he learns to avoid the other's territory and actual fighting occurs less and less.

At the same time nesting activities begin. From time to time a male disappears into the seaweeds and wriggles through one of the densest patches in the vegetation. On one such an occasion he starts an amazing performance: he creeps through a tuft of weed, turns round at the other side, pushes his head into the tuft in a different place, goes through again and so repeatedly traverses the tuft in every possible direction, describing loop after loop, all radiating from one centre. While he does so, sticky opalescent material exudes from the opening of the kidney-duct and after some time sticks to the plant. From there a continuous thread is drawn out, and as the fish moves on, this is pulled round and through the weeds, which are thus firmly bound together. This 'weaving' lasts for about 15 minutes, and is repeated several times every day.

Between these 'weaving' periods the male tears bits off the plants or picks bits up from the bottom and carries them to the nest, where he pushes them into the tuft. This behaviour, however, only gradually appears. At first the fish inclines towards a piece of weed and merely looks at it; later on he takes it in his mouth, but then leaves it again; still later he carries it away some distance before he drops it, and only after several hours or even days the action becomes complete. A gradual development like this through several stages of increasing activity is a well-known phenomenon in animal behaviour. It points to the conclusion that the animal is not merely reacting to its environment, which is a constant factor, but that there is an internal factor, known as the 'drive', which urges the animal to react in a specific way to its environment. This might seem rather a vague explanation if a wealth of evidence had not given strong support as to the reality of such a drive. It is now thought of as energy, accumulating in a 'centre' in the brain. In our stickleback, for instance, there would be a 'building centre', in which nervous energy slowly accumulates (possibly under the influence of hormone production by the ripening gonads) until the level of this energy, the drive, is high enough to evoke building activities, provided certain external stimuli are present. The activities, however, consume the energy of the centre and therefore the activity may, so long as the drive is not strong enough, break off at any time, no matter whether its function has been fulfilled or not. The external stimuli, according to this theory, merely release the energy of the centre and do not evoke the reaction directly.

'Fanning'

In the later stages of building the stickleback starts to 'fan'. He sometimes stands by the nest and with exaggerated movements of the pectoral fins he directs a stream of water towards it, keeping his position by using his tail. The function of 'fanning' is to supply the eggs with fresh, oxygen-rich water. But he will 'fan' before there is any need to do so. Apparently the drive to 'fan' is there before the function is needed.

The male simply has to wait till sooner or later a ripe female passes his territory. When that happens, how does he recognise her as a female? There is no sexual dimorphism in this species and apart from behaviour and the swollen appearance of a ripe female, sexes are indistinguishable. It is, therefore, interesting that sex recognition

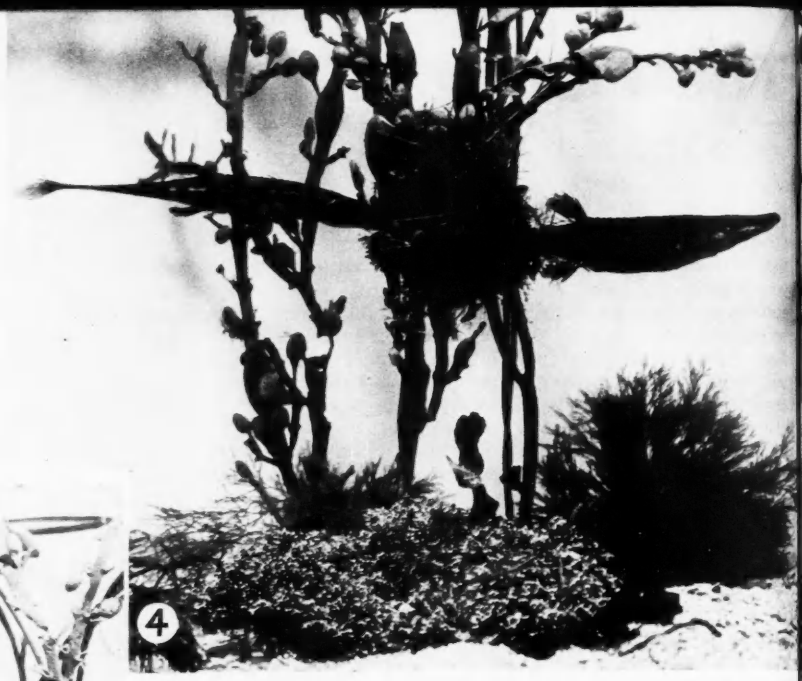

FIG. 4.—A female, distinguished by her swollen abdomen, is being chased by the male.

FIG. 5.—The male attacks the female, biting her tail and fins. If she is not ready to spawn she will swim away, but if she is ripe she will turn and swim towards him.

FIG. 7.—The male pushes his way into the nest from above, violently shaking the whole structure. He passes right through the nest almost at right angles to the female and fertilises her eggs with his milt.

FIG. 8.—A clutch of Sea Stickleback eggs, from another nest, magnified.

FIG. 9.—The male fans a current of water towards the nest. This carries oxygen to the developing eggs. The male stays on guard, fanning from time to time, until the eggs hatch.

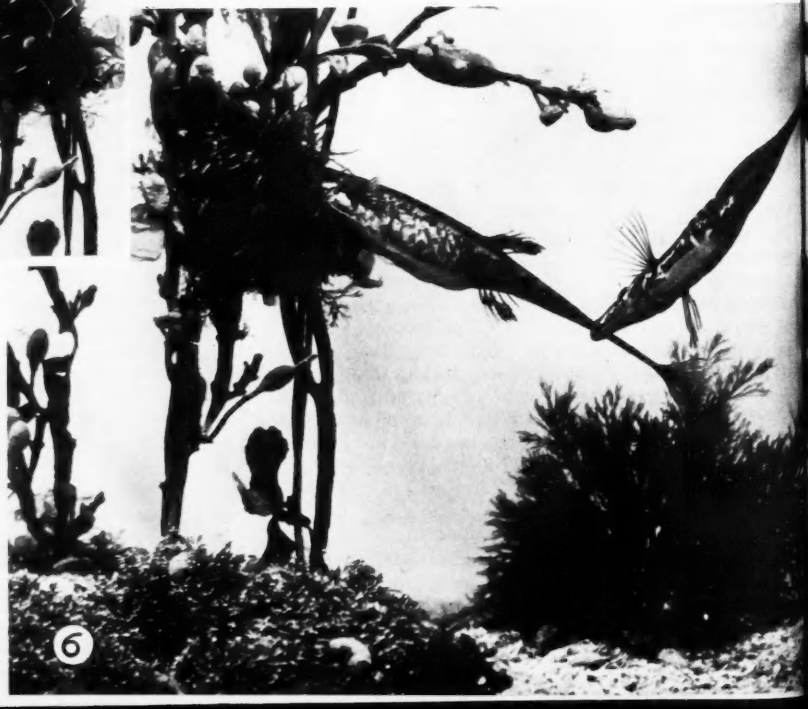

FIG. 6.—She has some difficulty in entering the nest. To encourage her efforts he bites her tail, but gently this time, not savagely as in his first attack.

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is based mainly on behaviour characteristics. At first the female is attacked like any male intruder. If she flees, the male chases her off, biting her in the tail or fins and nothing happens. If, on the other hand, the female is willing to spawn, she does not flee nor does she attack the male, but only turns towards him and immediately the male's behaviour changes completely. He darts off and jerks wildly with his snout in the nest. This seems to be a strong stimulus for the female. Before she follows, the attack may have to be repeated several times, but once she stands next to the jerking male, she immediately wriggles herself half-way through the nest and spawns. After some time, the male goes through, too, to fertilise the eggs, and he emerges first. He then starts to attack the female again, gradually becoming violently aggressive. The female thereupon flees from the territory and will never have anything to do with the offspring. After a while the male may accept other females and in this way collect a large number of eggs in the same nest—some hundreds per female. In the course of the three weeks which it takes the eggs to hatch, he becomes more and more occupied in fanning the nest. He fans longer at one time, and also he does so more frequently. Undoubtedly the eggs need more and more oxygen as the embryos develop, and the male's fanning appears to be well adjusted to this need.

When the young have just hatched, the male keeps them in the nest, but soon he cannot stop them swarming out in all directions. They do not at all resemble their parents at this stage, having peculiar blunt noses and a round head instead of the extremely elongated shapes of the adults. Their hunting behaviour, however, is fully developed right from the beginning. As soon as they detect a tiny prey they assume the hunting posture, curving their body into the shape of an S, and in this attitude they swim after the prey with a fluttering movement of the pectoral fins. When they are near enough, they suddenly straighten the body, so that they shoot forward, swallowing the food, exactly as the adults catch crustacea. This behaviour is purely innate and does not need to be learned, as is so often easily assumed by popular opinion.

POLYSTYRENE CROSSES THE ATLANTIC

WITH the announcement by Monsanto, that their Newport plant is about to produce polystyrene, this interesting and very useful plastic reaches a new phase in its development. So far, apart from one or two small-scale attempts, no polystyrene has been made in this country, and such quantities as have been fabricated here have been imported from the U.S. or Canada.

It may seem rather surprising that a material with such useful properties has hitherto been made only in America, but the reason is to be found in the exigencies of the late war. When in 1941, the Japanese overran S.E. Asia one of the unforeseen results was the loss to the Allies of the rubber-producing areas of the world. A tremendous impetus was thus given to the development of synthetic rubber, and the whole drive was concentrated in the U.S. The Baruch Committee was commissioned to investigate and make recommendations on the setting up of a synthetic rubber industry, and between 1942 and 1944 the Americans created just this. By 1946 they had produced over a million tons of various types of rubber, the most important of which was the so-called GR-S. As a chemical engineering feat this probably ranks next to the atomic energy project.

Now, the importance of all this to the development of polystyrene rests upon the fact that GR-S is a copolymer of about 75 per cent. butadiene and 25 per cent styrene. A large capacity for the production of styrene is therefore an integral part of the synthetic rubber industry. Since styrene is also the raw material for the plastic the Americans had produced the wherewithal for a big expansion in the manufacture of polystyrene.

When natural rubber became available once more, in spite of the fact that manufacturers were required by law to incorporate a proportion of synthetic material, consumption of the latter fell considerably. The surplus styrene, however, was taken up by the plastics industry, and as a result polystyrene output in the U.S. has leapt up. Thus in 1944 output was 10¼ million lb. By 1947 it had reached 95 million lb., and in 1949 it had more than doubled itself at 212 million lb.

This spectacular increase found no echo in this country, because of lack of home production and dollar difficulties. Current consumption here is of the order of 9 million lb. per year. The advent of a petro-chemical industry in Britain, however, has provided the necessary conditions for the manufacture of polystyrene. Petro-chemicals, for example, are making benzene and ethylene by their Catarole process, and by their synthesis produce styrene. British Petroleum Chemicals, a joint venture of the Anglo-Iranian Oil Co. and Distillers Ltd., will also be making the monomer, styrene. It is this monomer incidentally, which Monsanto will use when the styrene is in production at Grangemouth.

The growing popularity of polystyrene in America is due to two factors. First it is one of the cheapest of plastics, and therefore has a market advantage. Second, and just as important, its properties make it suitable for a large number of applications for which it 'fills the bill' more adequately than any other material.

For example, its outstanding electrical properties, particularly at high frequencies, make it very useful in radio and related fields. Its low water absorption is an added advantage because the presence of moisture is a frequent cause of electrical breakdown. This resistance to water also makes polystyrene dimensionally stable. It does not buckle and warp in moist atmospheres, as do, for example, celluloid and cellulose acetate.

Its attractive glass-like appearance, low density (it weighs about a fifth of an equal volume of glass) and chemical resistance, suggest its use for kitchen ware. Thus bowls, beakers, salad spoons and the like in polysteyrene, have made their appearance on the counters of the big stores. Incidentally, they can be easily recognised there by the metallic sound which they give when struck.

The chemical resistance and film-forming properties of polystyrene are responsible for a large outlet in paints and varnishes. The reaction between styrene and drying oils, such as linseed and tung oil has been used extensively in the last few years for the production of quick drying paints.

M. KAUFMAN.

The Brilliance of Lord Rutherford

SIR JOHN COCKCROFT, F.R.S.

Director, Atomic Research Establishment, Harwell

THE President of the Royal Society, in his anniversary address on St. Andrew's Day, told the Fellows of the Society of the plans which are being made to commemorate the name of Lord Rutherford.

When Rutherford came to Cambridge in 1895 from New Zealand to work with the Cavendish Professor, J. J. Thomson, he was living in a scientific world which believed that the atoms of the material world were unchangeable and indestructible. But the foundations for this belief were being undermined, first by Roentgen's discovery of X-rays in 1895, then by Becquerel's discovery in 1896 of the similar radiations emitted from uranium, and even more so by J. J. Thomson's discovery of the electron in 1897 which showed conclusively that the chemical atom was not the smallest unit of matter. So it was natural for the young and energetic research scholar to enter this new field, and he quickly established a great reputation. "We've got a young rabbit here from the Antipodes," wrote a Cambridge resident, "and he's burrowing mighty deep." Rutherford soon found out that the radiations thrown out by uranium consisted of two quite different forms . . . one of them behaving like J. J. Thomson's electrons, which he called the beta rays, and another radiation which he called the alpha rays. These alpha rays were to be one of the most important tools of his later life.

He took the problems of these radiations with him to McGill University in Montreal, where he was appointed MacDonald Research Professor of Physics in 1898. He collected round him an able band of research workers, including Frederick Soddy. In the next five years Rutherford and his school proved conclusively that the heaviest elements were spontaneously changing by throwing out Rutherford's alpha and beta rays. The alpha rays were shown to be atoms of the light element helium and the beta rays were shown to be electrons. By these processes the heaviest element, uranium, was transformed first through three lighter elements into radium—which Madame Curie had discovered—and from that by nine more changes into stable lead. A similar process of radioactive change was found to be occurring in members of the thorium family. These changes could not be speeded up by any known physical process, and the amount of energy which was released in the process was astoundingly large. Rutherford said that there was "reason to believe that an enormous store of latent energy was resident in the atoms of radioactive elements . . . energy which was derived from the internal energy of atoms. There seemed to be every reason to believe that the atomic energy of all the elements was of a similar high order of magnitude." By 1905, then, the doctrine of immutable atoms had been overthrown and the possibilities of atomic energy were dimly seen.

The next great phase of Rutherford's work was carried out in Manchester University, where he moved in 1907. At this time the structure of atoms was uncertain. They were no longer thought of as minute billiard balls, and speculation on their structure was very free, one school considering them to be rather like minute plum puddings with electrons as currants embedded in a sphere of positive electricity.

Rutherford started by working on the nature and properties of the helium atoms which he had found to be shot out of radioactive elements. In the course of the experiment he noticed that these high-speed atomic projectiles could be deflected slightly by collision with atoms of a gas or in passing through thin metal foils. One day when he was discussing in the laboratory the great magnitude of the forces required to deflect such very high-speed particles—they would cross the Atlantic in a fraction of a second—he turned to a young student, Marsden, and said, "What about trying whether you can get alpha particles reflected from a solid metal surface." To Marsden's surprise he found that a few of these projectiles did in fact bounce back. This was even more surprising to Rutherford: he said that it was as surprising as if a fifteen-inch shell had bounced back from a sheet of tissue paper. He puzzled over these results for nearly two years and finally, by remarkable insight, concluded that the atom must be like a miniature solar system—a central electrically charged sun, the nucleus, with electrons circulating round it like planets. This picture was confirmed by a series of beautiful experiments. Rutherford believed in the motto written above the entrance to McGill Physics Laboratory: prove all things.

From this discovery it was seen also that the properties of the different elements were determined solely by the nature of the central nucleus. The central nucleus could carry any number of units of positive electrical charge between one and ninety-two and for each unit of charge on the nucleus, one negatively charged electron could be attracted as a planet. The chemical properties depend on the electrons and so in turn on the nucleus. Many of you will remember that the work of the chemists had enabled them to arrange the elements in what is called the periodic table. In the top row you have only two elements: hydrogen (the lightest of all elements) on the left, and helium on the right. The next row starts with lithium at the left-hand side and works across, through beryllium, boron, carbon, nitrogen, oxygen and fluorine to neon. In the next row you start with sodium and work across to argon. The properties of the elements repeat themselves in passing down from one row to another. This was now all explained by the planetary atom of Rutherford, for the electrical charge of the nucleus increases steadily from one to ninety-two as we work through successive rows of the periodic table. Successive shells of electrons are filled, one shell to each row of the table. The Manchester work of Rutherford not only gave us a picture of the incredibly minute world of the atom, but it explained at once the chemical regularities of the elements.

Already, Rutherford's discoveries were sufficient to have placed him amongst the immortals, but one last great period of work was still to come. He moved to Cambridge in 1918 and became the fourth of the illustrious line of

Cavendish Professors. He was experimenting again with his alpha particles, shooting the high-speed helium atoms into nitrogen gas in a sort of nuclear billiards to see how the atoms were knocked about. To his surprise another kind of atomic particle appeared and it turned out that these were hydrogen atoms. Again Rutherford's remarkable intuition led him to the correct conclusion. His helium atoms were entering the nitrogen nuclei and knocking out hydrogen atoms, thus transforming nitrogen into a form of oxygen, which is three units of mass heavier. The rapidly growing school of the Cavendish Laboratory now concentrated on this problem. When I first worked in the laboratory in 1922, Rutherford used to shut himself up for an hour or so every day in a darkened room with selected research students, looking for a minute at a time through a microscope at the faint scintillations of light produced when the nuclear fragments hit a zinc sulphide screen. With this remarkably simple apparatus the controlled transmutation of matter was achieved for the first time.

These experiments were trying and difficult, and it was characteristic of Rutherford that he encouraged 'his boys', as he called us, to develop new methods which in the end produced a new branch of science—nuclear physics. New apparatus producing high voltages and long sparks was brought into or built in the laboratory, and by these means copious streams of high-speed hydrogen atoms were produced to take over the work of transmutation from Rutherford's alpha particles. At the same time, other groups working in cellars and dim corners were developing new methods of recording the impact of high-speed atomic particles. This work bore fruit in that *annus mirabilis* of 1932 when Chadwick discovered the neutron, Walton and I transmuted the light elements with hydrogen atoms, and Blackett and Occhialini showed how radiation could be transformed into matter. The discovery of the neutron by Chadwick led in 1938 to the discovery of the fission of uranium by neutrons and from here to the final achievement of the release of nuclear energy. These discoveries, with all their far-reaching consequences, rest therefore on the foundation of Rutherford's work, though at the time of his death, in 1937, he himself thought that the outlook for gaining useful energy from atoms did not seem promising.

Rutherford's scientific work was well summed up by his friend, Sir James Jeans. Jeans said: "Most of his investigations were key investigations . . . each brilliant in its simplicity of conception and far reaching in its consequences. In his flair for the right line of approach to a problem, as well as in the simple directness of attack, he often reminded us of Faraday. Voltaire once said that Newton was more fortunate than any other scientist could ever be since it could only fall to one man to discover the laws which govern the universe. Had Voltaire lived in a later age he might have said something similar of Rutherford and the realm of the infinitely small, for Rutherford was the Newton of Atomic Physics."

In considering the technological consequences of Rutherford's work we might again think of Faraday. In 1831 Faraday discovered that a moving magnet will produce an electric current in a coil of wire, and with that observation opened the way to the development of electric power which has transformed our way of living and working and enormously increased man's productivity and standard of life. But it was not till forty-eight years later that a dynamo lit Edison's first practical electric light, and two more years before the first central electricity station came into use. No one living in 1831 could have predicted the full consequences of Faraday's work, and I do not think that anyone living to-day can predict the full technological consequences of Rutherford's work. If Rutherford were alive to-day he would be thrilled by the sight of the powerful atomic research piles at Chalk River and Harwell, generating energy, quietly and safely, producing the radioactive isotopes which are helping the biologist to understand the world of living matter and providing for physicists new and powerful tools of research. We are only beginning, however, to see our way to applying nuclear energy to the development of electrical power.

What sort of man was Rutherford to have achieved so much? Needless to say he was a man of great intellectual power, but Rutherford was much more than this. He was a man of wide reading, shrewd in all practical things, a great judge and leader of men, and a man of profound wisdom, much sought after for his counsel in the larger world. For five years he served the Royal Society as its President; he did much to encourage the application of science to industry, and in particular to encourage the development of the Department of Scientific and Industrial Research to its present status in our country.

Rutherford was not one who journeyed in strange seas of thought, alone. He was a man of exuberant vitality; he loved to have young men about him, sharing his enthusiasms, generating their own ideas by the intense cross-fertilisation of discussion, producing results which no one man, however great, could have realised. Those who worked with Rutherford caught to some degree this infection and way of working. During the war you could see this spirit of the Cavendish burning fiercely in huts and stables on the Swanage headland and Hampshire coast, generating the micro-wave radar which contributed so much to our victory. To-day you can still see the influence of Rutherford in the work of his students.

In the last decade of his life Rutherford came to dominate the scientific world as no other scientist has ever done. We can say of him, rather as Planck said of Clerk Maxwell, by his birth and early training he belongs to New Zealand, by his personality he belongs to the British Commonwealth; by his work he belongs to the whole world. The Royal Society propose to commemorate his name by providing for Rutherford Scholars and Rutherford Lecturers who, like Rutherford, will carry the torch of learning between our member nations. There can be no more fitting memorial.

The cover photo of Rutherford in the Cavendish Laboratory comes from *Rutherford*, the official life and letters by Prof. A. S. Eve. Reproduced by kind permission of Cambridge University Press, who published the book in 1939.

Sampling the Sea-bed

NORMAN HOLME, B.A.

As our knowledge of the topography, geology, fauna and flora of the land masses of the world becomes more complete, more and more attention is being paid to exploration of the two-thirds of the earth's surface which are covered by the oceans.

Recently in DISCOVERY (November 1948), Professor Hans Petterson described the apparatus used on the Swedish *Albatross* expedition for obtaining long cores of sediments from the bottom of the deep sea. In the deeper parts of the oceans there is a slow but continual rain of minute animals from the surface layers which, mingled with particles of mud and volcanic ash, accumulate to form the bottom sediments. The core samples obtained on the *Albatross* expedition make possible the study of the stratification of animal remains in such sediments, so enabling scientists to collect the data needed to learn about the climatic and other changes in the world's history.

In the nineteenth century many expeditions were made to investigate the fauna of the oceans' depths, the most famous of which was that of H.M.S. *Challenger*, from 1873 to 1876, which obtained samples from all parts of the globe.

Although under one-tenth of the area of the oceans has a depth of less than 100 fathoms, it is this area, the area covered by what is known as the Continental Shelf, which is of particular interest to the marine biologist. This is mainly due to the economic importance of fisheries in the shallow seas, of which the North Sea is the most familiar to British readers.

In shallow water there is little deposition from the overlying water, and the bottom sediments are composed of sands and gravels mainly derived from erosion of the rocks in coastal areas.

Because of the coarser nature of the deposits on the Continental Shelf, the problems of obtaining samples of them are rather different from those in deeper water. Owing to the relative impenetrability of sand, bottom-samplers must be heavily weighted or depend on some form of auxiliary power. The lack of cohesion of coarse soils renders it difficult to retain the sample while it is being hauled to the surface.

The earliest means of obtaining a sample of the sea-floor was with a sounding-lead to the base of which was attached a lump of tallow to which the soil would adhere. Much of the sample might drop off as the lead was hauled in, but it is on information obtained by this method that the details of the deposits recorded on Admiralty and other charts have been prepared.

The need for obtaining fairly large samples of the bottom has been long felt by marine biologists. In the bottom soils are to be found many burrowing invertebrates (Fig. 8), which, besides being of interest in themselves, are of economic importance as they form the food of bottom-feeding fish, such as plaice. The density and vertical distribution of the bottom-fauna is such that several samples each covering about one square foot in area and one foot in depth would be required for an accurate assessment of the density of animal population. No instrument capable of taking such a sample in the open sea has yet been devised.

The dredge is one of the oldest means of collecting a sample of bottom soil with its contained animals. It consists of a heavy rectangular iron frame, to which is attached a bag of canvas or netting, and two arms by which it is towed along on the end of a rope or cable (Fig. 1). Dredges have been used on many expeditions in order to get a rough qualitative picture of the bottom fauna, but the samples brought up are not very satisfactory for a number of reasons. While being towed, the dredge has a tendency to ride over the ground instead of digging in, and provides uneven samples. In addition it does not dig deeply enough to capture many members of the burrowing fauna. While being hauled up much of the soil may be lost; thus we find that when dredging on an area of sand off Plymouth the dredge often comes up empty save for a few stones and shells, all the sand having been washed through the net.

In recent years many attempts have been made to obtain more quantitative samples of the sea-bed. Various types of apparatus have been improvised, most of which a precision engineer would consider far from perfect, for they must be designed to withstand knocks against the ship's side, and corrosion by sea water, and they must literally operate with 'sand in the works'. The diversity of these samplers reflects not only the fact that no fully efficient one has yet been devised, but also the different needs of various investigators, and the type of soil to be sampled.

Core-samplers

Core-samplers, of which there are many kinds, obtain a stratified core of the bottom deposits; but owing to the lack of cohesion of soils other than muds the coring tube must necessarily be of narrow bore. To the steel coring tube are attached weights sufficiently massive to drive it into the soil. The sampler is lowered vertically from the ship on a rope or steel cable. Owing to the drift of the ship caused by winds or currents it is rarely possible to lower the corer quite vertically, and often the cable pays out at quite a considerable angle. Although the penetration of the coring tube may be increased by lowering it more rapidly, safety considerations limit the rate at which it can be allowed to drop to around 10 ft. per second.

Hvorslev and Stetson have recently described a core-sampler which falls freely for the last few feet of its descent, thereby enabling it to drop quite vertically and at a velocity higher than 10 ft. per second. The sampler is suspended from a steel cable through a hook on a release arm attached to a pilot weight. The pilot weight is about twenty feet below the lower end of the coring tube (Fig. 2). When the pilot weight strikes the sea bed the tension on the arm is released, and the corer falls freely, being guided in its descent by a fin. It is pulled up again by a bight of chain which is loosely coiled up during the early part of the descent. A modification of this corer has recently been used by Professor W. B. R. King and M. N. Hill to obtain samples of rock in the English Channel. When the coring

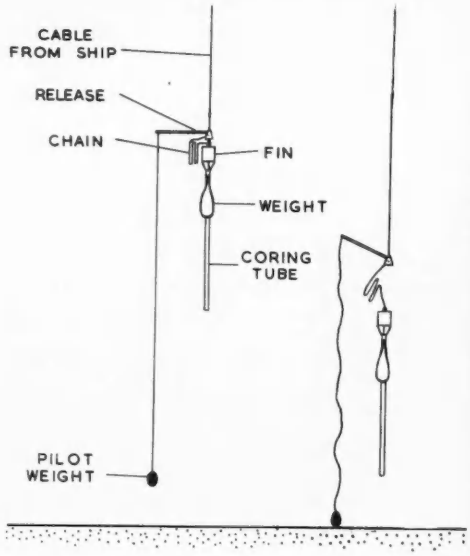


FIG. 1 (*left*).—Dredging. FIG. 2 (*right*).—The free-fall core-sampler, showing release of the coring tube when the pilot weight strikes the sea bed. (After Hvorslev and Stetson.)

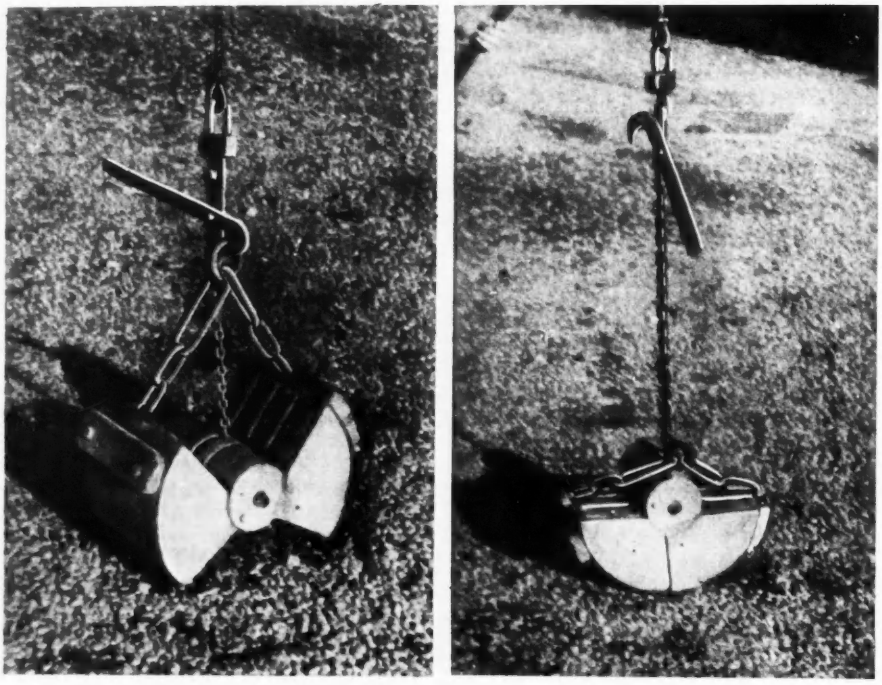


FIG. 3.—The Petersen grab, open (*left*) and closed (*right*).

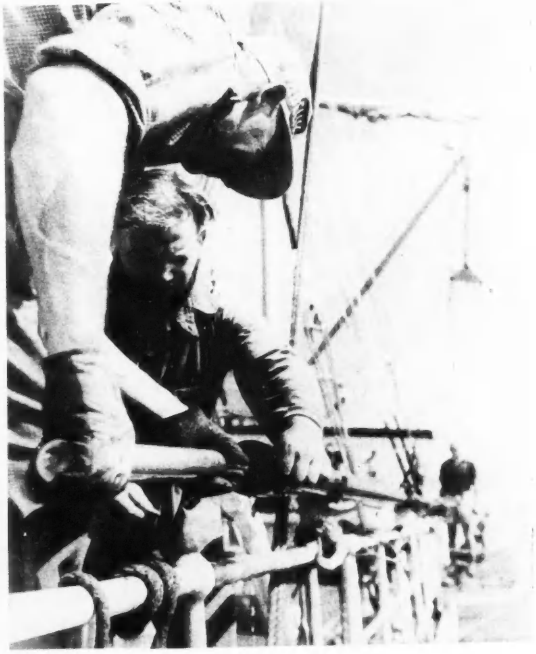
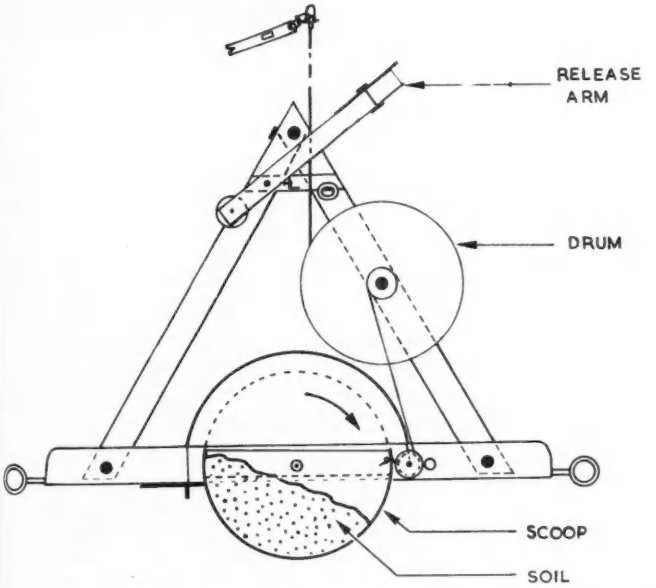


FIG. 4 (*left*).—Using the scoop sampler on R.V. *Sabella*, research ship of the Marine Biological Association. FIG. 5 (*right*).—The Piston Core Sampler being prepared for use on the Swedish *Albatross* expedition. (Full details about this sampler were published in *Discovery* in November 1948.)



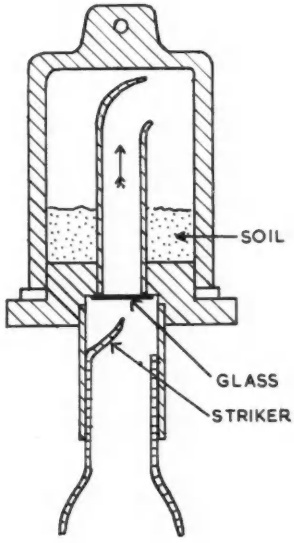


FIG. 6 (*left*).—Diagram of the scoop sampler, showing soil sample. The position of the scoop during the descent is shown by the broken line. (After Holme.) FIG. 7 (*right*).—The Hunt sampler. The funnel-shaped piece at the bottom (to which the striker is attached) slides up when the sampler hits the sea bed, so breaking the glass. Soil is then 'sucked up' into the air chamber, where it is trapped as shown. (After Hunt.)

tube penetrates sandstone, chalk or clay these form a plug, so retaining a core of the overlying sand if there is a layer of sand covering the rock. If the tube does not become plugged in this way it usually comes up empty. Although several types of flap valve have been attached to the lower end of the tube it has not yet been possible to obtain a satisfactory core of sand unless the tube becomes plugged by rock.

Samples Containing Animals

Owing to their narrow bore, coring-tubes are unsuitable for capturing the larger animals living on the bottom, and so for quantitative studies various types of grab are employed. These take a shallow unstratified sample of relatively large area. Grabs are often heavily weighted in order to penetrate deeply into the soil, but the sample is actually taken when the cable is being wound in, just before the sampler leaves the bottom. While being lowered a release mechanism prevents the grab closing; when the grab reaches the bottom the release is actuated and the tension of the cable, as it is being wound in, closes the grab.

The *Petersen grab* (Fig. 3) has been extensively used for sampling, particularly where the soil is of soft mud. It is not very effective on sands or gravels, however. Not only does it fail to penetrate sufficiently deeply into the soil, but while being hauled up, the finer constituents of the soil may be largely lost owing to the presence of a stone or shell that has become wedged between the jaws, and so prevents them from closing. The *Van Veen sampler* improves on the Petersen grab by having long arms attached to the closing mechanism so that a very much greater leverage is obtained to close the jaws.

A sampler designed for use on sands and gravels is shown in Figs. 4 and 6. Here the sample is taken by a single semi-circular scoop which rotates through 180°. It will be seen that there can be little loss while the sampler is being hauled to the surface. As in other grabs the closing mechanism is actuated as the sampler begins to be hauled up. By the use of two drums (one large and one small) rotating side by side one can exert a force equal to several times the weight of the apparatus to close the scoop. This sampler has been found to bring up reasonably satisfactory hauls, and gives better samples of the burrowing fauna than the Petersen grab. In one trial the 'scoop-sampler' brought up to the top three inches of several burrowing razor shells (*Ensis*), while the Petersen grab failed to take any. A dredge haul taken at the same time took the top half inch of this species. (*Ensis* is a long narrow shell living nearly vertically in the sand, with its upper end near the soil surface; the length of it cut off by the samplers is therefore a measure of the depth of their 'bite' on this ground.)

Several attempts have been made to utilise some form of auxiliary power to drive a coring tube or other device into the soil. Some of these have made use of the hydrostatic pressure of the water—the same pressure which operates in the well-known Cartesian diver—by lowering a sealed chamber of air and opening it on the bottom. The 'suction' produced in compressing the air may be used directly to 'suck up' a sample, or to drive some form of boring machine.

Professor J. Joly has described an ingenious machine, unfortunately never used, for boring into rocks on the sea bed. A large air chamber was coupled to four cylinders with pistons attached to a coring tube. The 'suction' produced when the air was compressed caused a semi-rotary movement to be imparted to the tube, so enabling it to bore into the rock. It was calculated that an air chamber of a capacity of one cubic foot would develop 0.4 horse-power for a period of thirty-one minutes at a depth of 1000 fathoms.

A simpler method of utilising water pressure is found in O. D. Hunt's 'vacuum' sampler (Fig. 7). A chamber of air sealed by a glass plate is lowered, and on striking the bottom the glass is broken and a sample 'sucked up'. The soil is trapped as shown in Fig. 7. This apparatus takes a small unstratified sample, the great merit of which is that it is not subject to loss while being hauled up. When the liner *Egypt* was being salvaged it was found that although the large grabs used were able to pick up bars of gold they were unable to pick up gold coins, so a 'suction' machine similar to Hunt's sampler was used for the latter purpose.

The *Piggott coring apparatus* makes use of an explosive charge to drive it into the bottom. Cores of up to 10 ft. in length have been obtained at depths of nearly 3000 fathoms. In view of the much longer cores since obtained on the *Albatross* expedition, with the Kullenberg sampler illustrated in Fig. 5, the Piggott 'gun' must have been superseded to some extent.

In order to take a sample with any of the corers and grabs mentioned above the ship must be stopped. However, a recent American device, the *Underway bottom-sampler*, enables a small sample to be taken while the ship is still steaming. This consists of a small heavily built coring tube with fins; it is thrown overboard on the end of a wire which is rapidly paid out from the ship. The fins enable it to fall almost vertically, and on striking the bottom the sampler reverses so that the open end of the coring tube comes up first, so preventing loss of soil.

Use of Submarine Cameras

While it is now possible to obtain reasonably satisfactory samples for geological purposes both on the Continental Shelf and in the deep sea, the large size of the sample required for estimation of numbers of animals renders most samplers relatively ineffective for this purpose. The size and weight of the apparatus is severely limited by difficulties in handling on board a small research ship. It is possible that some of the problems confronting the marine biologist can be more readily solved by indirect means. Underwater cameras have been recently used both in this country and in America for obtaining photographs of animals living on the surface of the sea bed. The distribution of sparsely distributed animals such as starfish can be more readily plotted by this means than by grab samples, for example. In addition, such photographs reveal the presence of certain species by showing their burrows on the surface of the soil.

READING LIST

A good account of dredging methods is given in Chapter 9 of *Science of the Sea*, edited by G. H. Fowler and E. J. Allen, Oxford, 1928. A discussion on "Methods of Exploring the Ocean Floor" is contained in *Submarine Geology* by F. P. Shepard (New York, 1948).

Descriptions of the samplers described in this article can be found in the following:

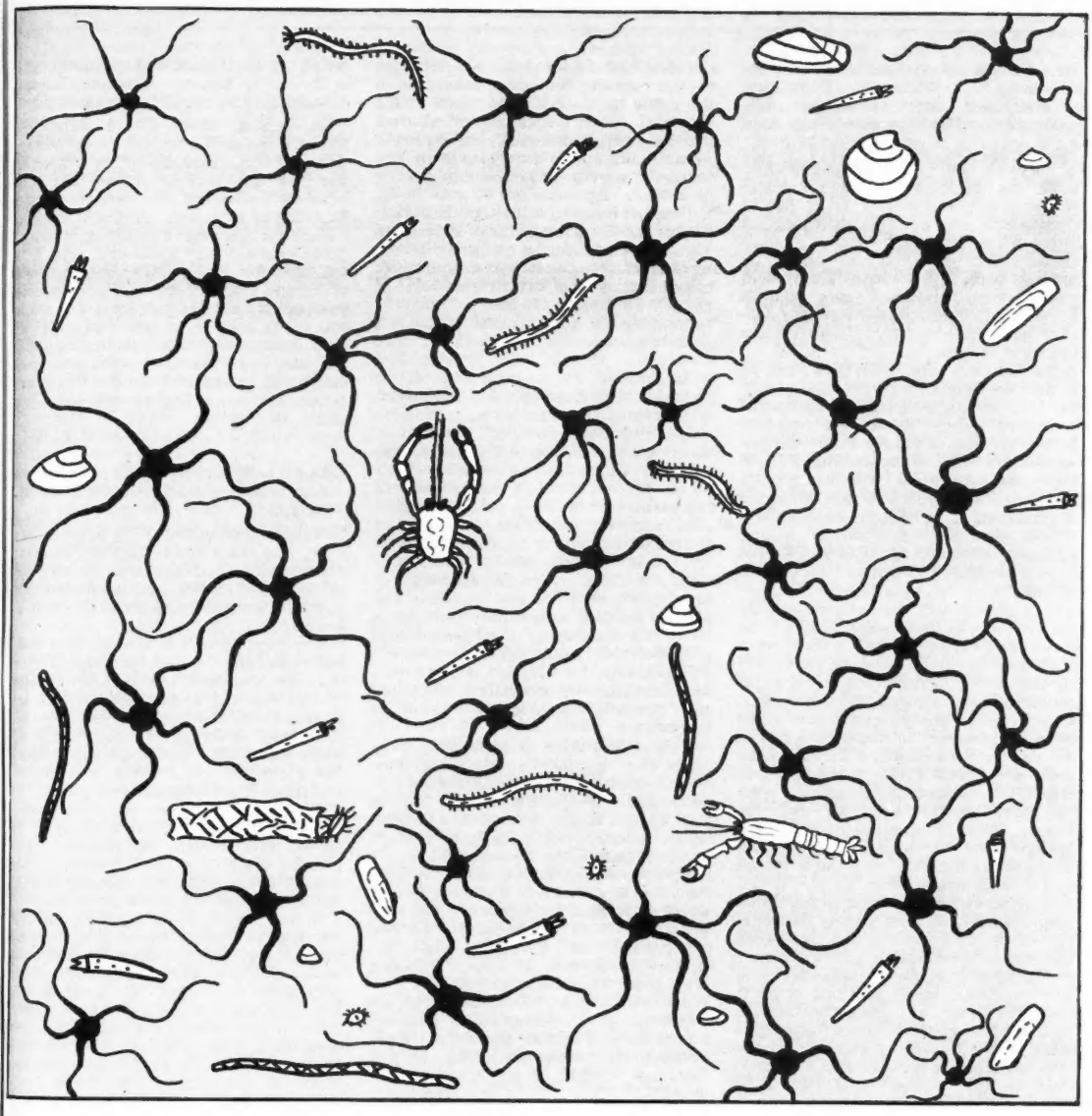


FIG. 8.—Community of bottom-living animals living in muddy sand off the S. Devon coast. The area shown is ¼ sq. metre. Many Brittle Starfish (*Amphiura filiformis*), a crab (*Corystes cassivelaunus*), a burrowing prawn (*Callianassa subterranea*) and various polychaete worms and lamellibranch molluscs may be seen.

M. J. HVORSLEV and H. C. STETSON, 1946. *Bulletin of the Geological Society of America*, Vol. 57, pp. 935–50.

C. G. J. PETERSEN, 1911. *Report of the Danish Biological Station*, No. 20, pp. 47–50.

H. M. THAMDRUP, 1938. *Journal du Conseil (Conseil Permanent International pour l'Exploration de la Mer)*, Vol. 13, pp. 206–12.

N. A. HOLME, 1949. *Journal of the Marine Biological Association*, Vol. 28, pp. 323–32.

J. JOLY, 1914. *Scientific Proceedings of the Royal Dublin Society*, Vol. 14, pp. 256–67.

O. D. HUNT, 1926. *Journal of the Marine Biological Association*, Vol. 14, pp. 529–34.

C. S. PIGGOTT, 1936. *Bulletin of the Geological Society of America*, Vol. 47, pp. 675–84.

K. O. EMERY and A. R. CHAMPION, 1948. *Journal of Sedimentary Petrology*, Vol. 18, pp. 30–33. (Underway sampler.)

M. EWING, A. VINE and J. L. WORZEL, 1946. *Journal of the Optical Society of America*, Vol. 36, pp. 307–21. (Underwater camera.)

H. G. VEVERS, 1951. *Journal of the Marine Biological Association*, Vol. 30 (in the press). (Underwater camera.)

The Bookshelf

The Growth of Scientific Ideas. By William P. D. Wightman. (Edinburgh, Oliver and Boyd, 1950, pp. 495, 35 figures, VIII plates, chronology, 25*s*.)

THIS book, the author's third in the 'history of science' field, is an ambitious work, the result of prodigious industry and considerable thought. (It is also of considerable size, and though the author refers to it as "this little work" it contains about a fifth of a million words.) Its range is wide, and traverses a period of more than two thousand years. It must be included among the more serious contributions made in recent years to the history of science.

No scientific entity, writes the author, be it atom or organ or wave, is *merely* itself, but is constantly evolving in a context of associated ideas. "Hence the necessity for a knowledge of history; not to 'liberalise' science, but to understand it." In these few words Dr. Wightman parts company from people who look on history as something to be added in order to give science some claim as a part of culture; instead he insists on the history of science in its own right as an essential part of our culture.

In a general way the author's opinion can be said to be that a scientific idea is the result of a struggle, not only in the mind of the creator but in the social and ideological context of his environment. This is, of course, a *human* struggle and the recognition of this fact completes the case for the study of the history of science as a part of our culture. In addition, a scientific idea, being an evolved entity of the sort described, is balanced, sometimes precariously, between the past and the future. Thus Einstein has improved on Newton and doubtless someone will improve on Einstein. This is the substance of Dr. Wightman's thesis.

Anyone who has assimilated the above points is ready to start reading the book. He will find that some subjects have been omitted, largely because of the author's own predilections, for he makes no claim to comprehensiveness, and one in particular, the theory of organic chemistry, is left out because it is in a sense "a domestic affair". The included topics are divided into two separate groups—Part I is called "Matter and Motion" and Part II is "Nature and Life". The former occupies some two-thirds of the whole book, and can be said to be in essence physics and mechanics with some astronomy and chemistry. Part II is of course concerned with biology. Because of the author's schema, each chapter is devoted to the discussion of one main idea, and so any one scientist can figure in more than one chapter, which is a little disconcerting until one gets used to the system, and there is naturally not a continued and unvaried chronological sequence from the first page onwards.

No criticism can be made of the factual accuracy of this work, and the author has no political bias to make him choose only the facts that will prove a dogma. His devotion to his own thesis is never rigid enough to make him obscure the truth in the desire to make a case. Two of the chapters, those on the most abstract themes—energy and fields of action—were checked by Professor Max Born, and four others were read in manuscript by Sir Edmund Whittaker.

The style is readable, though the author has been led into two errors of exposition. The first error is that of confusing spoken lectures with the printed word. A lecturer can put in an aside, and at once a lift of an eyebrow or a glint in the eye betrays it; so his audience, greatly entertained, is not distracted from the main business. The same device does not work in print. It is to be doubted, for instance, whether the statement that "pure chemical substances, so different from plum cakes, are formed only of definite proportions" will produce anything but irritation in the reader. The addition of "in which politicians may see an omen" to a sentence about Euler, and conservative systems is pure platform facetiousness. The same confusion of lecturing with writing no doubt accounts for the bewildering array of italics scattered about every page, the equivalent of vocal emphasis in the lecture room. The lecturer's potted commentary even creeps into the bibliography, where we are told that Crowther's *Social Relations of Science* is "readable but highly informative". How can that *but* be justified, unless the word *readable* is used as a term of contempt.

The second error of exposition arises from what is evidently a thorough misunderstanding of what constitutes popular writing. Dr. Wightman seems to look at it as being a sort of ornament or folderol added to serious text. He hints as much in the preface when he writes: "Lest the story should seem colourless I have enlivened its course with such biographical detail as seemed appropriate." He is as good as his word, and so we are informed on p. 229 that Berthollet was "fat, good-natured, and ingenious" though there is no indication of what relevance his corpulence had to his beliefs about the inconstancy of composition of chemical compounds. A similar jamming of the pill comes in the *facetiae* scattered as chapter headings—"When is an Atom not an Atom?", "The Burning Question", "'The Subject of the Verb to Undulate'".

Let it be said at once that if Dr. Wightman does indeed hold the above view of popularisation, it is heresy. Popularisation is a separate discipline, and the number of people in this country really skilled at it can be counted on one's fingers.

But we must not be over-critical, for Dr. Wightman's efforts have all been honestly made in order, as he doubtless hopes, to increase the readability of his book. He can be assured that his text, if pruned of facetiousness and digressions and ornament, would be the better reading and gain in dignity.

C. L. BOLTZ.

Safety in the Chemical Laboratory. By H. A. J. Pieters. (London, Butterworths, 1951, pp. 258, 15*s*.)

THIS manual, issued to all laboratory workers in the Netherlands State Mines, describes the hazards which arise in handling apparatus and chemicals. The risks are mechanical, electrical, toxic and from fire or explosion. Tables at the end summarise limiting conditions, precautions, first-aid and treatment. As it is unusual for universities or technical colleges to give instruction in safe working this book should fill a gap, for it will enable the young chemist to learn not only his own occupational risks, but incidentally the way to conduct industrial processes safely and in line with statutory requirements, for which English references are given.

F. E. W.

Lysenko is Right. By James Fyfe. (London, Laurence & Wishart, 1950, pp. 65, 2*s*. 6*d*.)

IN this little pamphlet of 64 pages James Fyfe, who is a Cambridge plant breeder, arrives at the conclusion that the position taken in the U.S.S.R. by Lysenko and his followers is scientifically sound and fruitful in practice.

The point of view of the reviewer both before and after he read the pamphlet was that the position taken by Lysenko and his followers is a scientifically illiterate extension of the doctrine of acquired characters involving an unfounded and naïve belief that teleologically induced hereditary changes are possible and of practical value to agricultural science.

To this point of view he would add a rider expressing his regret that Mr. Fyfe should have so mixed his biological and political drinks as to put himself into that state of intellectual coma characteristic of Party members and fellow-travellers.

It is altogether fitting to point out that although the title of the book states that "Lysenko is right", it does not contain a reasoned exposition of why the author thinks that he is right. Mr. Fyfe restates the claims with a slight favouring of speculation which defies all the canons of logic: Lysenko says they are right, Mr. Fyfe says they are right, the Party says they are right. In fact what is said three times must be true.

The whole Lysenko case, so far as Mr. Fyfe is concerned, rests on hearsay evidence; his attitude towards such evidence should, as a scientist, be one of suspended judgment. He knows as well as I do, if he will get off his soap box, that the principles of genetics (on which he presumably got his M.Sc.) represent the considered conclusion of thousands of meticulously conducted experiments and that scientific territory has been won for ever, which in spite of Stalin's avowed belief in the inheritance of acquired characters, is now an inherent part of the cultural heritage of our time.

His attitude is not that of a scientist. It is the attitude of a biological Jehovah's

Witness; it is the attitude of a typical line-toeing, hook-line-and-sinker-swallowing Party Member.

"Michurinism," he says, "is an experimental science and its theories and hypotheses are to be checked by appeal to experiment and observation and tested in practice." If Mr. Fyfe means by this sentence that there is the slightest scientific evidence that these theories and hypotheses have been verified by experiment he is wilfully misleading both himself and his readers.

The reviewer invites Mr. Fyfe to undertake this task himself, in the confident belief that the outcome of the work will be another book entitled *Lysenko is wrong*.

S. C. HARLAND.

The Art of Botanical Illustration. By Wilfred Blunt. (London, Collins, 1950, pp. 304, 35 black and white plates and 75 text figures, 21*s*.)

Drawings of British Plants. By Stella Ross-Craig. (London, G. Bell & Sons, pp. 77, Parts 3 and 4, 9*s*.)

Uncommon Wild Flowers, III. By John Hutchinson. (Penguin Books, Harmondsworth, Middlesex, 1950, pp. 254, 203 black and white illustrations and 32 photographs, 2*s*. 6*d*.)

GIBBON, in his review of Arab science (*Decline and Fall*, Chapter III), wrote—"Botany is an active science, and the discoveries of the torrid zone might enrich the herbal of Dioscorides with two thousand plants". Botany is still an active science, but after reading accounts of some of its current activities, it would be easy, if perhaps unkind, to echo the words of Anatole France in *Monsieur Bergeret à Paris*—"Et puis, il ne savait pas où il voulait aller. On en voit comme ça, des collignons qui ne connaissent pas votre rue, et qui vous roule indefiniment dans des chemins impossibles en clignant de l'oeil d'un air malin. C'est énervant."

Fortunately there is nothing to fret the nerves in some recent publications which wed the work of the artist to that of the botanist, for they show, as very much needs to be shown in the present-day world, that there is still deep comfort in culture, and solace in the contemplation of beauty. All plant-lovers, whether they are or are not professed botanists, will find help, and delights both old and new, in Wilfred Blunt's *The Art of Botanical Illustration* (New Naturalist No. 14), in Miss Ross-Craig's *Drawings of British Plants* Parts 3 and 4 (G. Bell & Sons), and in Dr. John Hutchinson's *Uncommon Wild Flowers* (Pelican Books). These books are of the kind which, it may be hoped, will hold botany in the primrose path which does *not* lead to the everlasting bonfire.

The Art of Botanical Illustration is so packed with skilfully chosen illustrations accompanied by a charming explanatory text, that many words would be needed to describe the book justly and fittingly. Reference may be made, perhaps, to a few points, not necessarily because they are the most important, but just because they are a few of the many good things which have interested the writer of this note. The reproduction of Dürer's 'Das grosse Rasenstück' shows what can be done with the commonplace when genius takes it in hand. A whimsical *Manypeeplia upsidownia* by Edward Lear, and the fanciful record by Worthington G. Smith of one of his adventures—perhaps not really so funny as some of his drawings of fungi—give a welcome touch of frivolity. The studies of the Madonna lily, ranging from *c*.1550 B.C., almost to the present day, show what a lasting appeal a fine plant can have. One of the drawings (*c*.1430 A.D.) depicts a lily with a branched influorescence, and, though the floral segments are somewhat wide, this figure may indicate that the Salonika stock of the Madonna lily reached northern Europe much earlier than is commonly supposed. An attractive little mystery story is built around various illustrations of the meadow saxifrage.

Mr. Blunt is not content with delighting his readers with his text and his pictures: he encourages them to draw plants for themselves. Not only does he provide a wealth of instruction from the work of W. H. Fitch, whose drawings are familiar to the hundreds of thousands who use the illustrations for *Bentham & Hooker*, but he also draws on the experience of Miss Snelling and Miss Ross-Craig, two famous plant artists now working at Kew. The issue of parts 3 and 4 of Miss Ross-Craig's *Drawings of British Plants* puts more of her lovely line drawings into the hands of grateful botanists. Part 3 has 77 plates illustrating the Cruciferae, and the 26 plates of part 4 carry on the work as far as the Frankeniaceae. Plant lovers are but the more greedy for the very many drawings of British plants which it is hoped will follow in due course from Miss Ross-Craig's pen.

Uncommon Wild Flowers adds a third volume to Dr. Hutchinson's series on British plants. The book contains a number of attractive photographs of some of our scarcer wild plants in their native haunts, as well as many of his characteristic drawings and descriptions. It can but be hoped that readers of these widely dispersed books will not be tempted to collect the plants indiscriminately, but will respect them and leave them to maintain their place in the countryside.

So long as botanists and artists delight and instruct us with finely illustrated books about whole plants as they grow there is no need to despair of the republic of botany.

B. BARNES.

The Physical Properties of Glass. By J. E. Stanworth. (London, Oxford University Press, 1950, pp. 224, 21*s*.)

THIS new volume in the series of Oxford Monographs on the Physics and Chemistry of Materials is well up to the standard of its companions.

In spite of the antiquity of the glass industry and the comparatively early date at which scientific investigations (in the modern sense), were applied to it, the modern glass technologist will be the first to admit that there are still many aspects of his subject in which he is guided by tradition and empirical experience rather than by scientific understanding. Progress in recent years has been rapid, and major advances have been made in the knowledge of the relations between the chemical constitution of a glass and such physical properties as density, refractive index and colour. Dr. Stanworth provides a lucid and readable account of these developments, but, commendably, he also devotes much of his space to a summary of the position in the more controversial subjects of the mechanical and electrical properties of glass.

This book makes a valuable addition to any general scientific library, and it will be a necessity to anyone directly concerned with the behaviour of glass.

The Proper Study of Mankind. By Stuart Chase. (London, Phoenix House, 1950, pp. 288, 16*s*.)

COMING from an author of the calibre of Mr. Chase, this book is rather disappointing. It seems hardly worth while to write some 300 solid pages with the sole aim of convincing the reader of 1950 that social science offers the only hope for man to control himself. A pamphlet a fraction of the size would have met the case, possibly with more telling effect.

In a book which attempts to explore the possibilities of applying scientific method to the study of human relations it is rather disturbing to find a passage like this:

"The physicist Richard C. Tolman of the United Nations Atomic Energy Commission once assured me that in his opinion the Russians would have accepted the Lilienthal-Acheson plan for the international control of atomic energy if they had been confident that it was made in good faith. The plan was so generous that the Kremlin was sure there was a catch in it somewhere. This is as tragic an example of communication failure as we can find anywhere."

The reader might be tempted to think that taking an opinion, and a questionable one at that, for an established fact to support a thesis is as good an example of unscientific reasoning as any that the author so heartily condemns. Nor does it seem fair to Machiavelli—and to scientific accuracy—to lump the great Florentine together with Marx, Malthus and Adam Smith as a framer of magnificent but unsupported hypotheses.

Mr. Chase rightly complains about the inadequacy of most definitions of scientific method, but his own effort at defining its essence in ten rather lengthy points is hardly an improvement on existing texts. Indeed, the definition of Colin Clark, which he quotes elsewhere in a different context, is as good as any and far shorter than most:

1. The careful systematisation of all observed facts:
2. the framing of hypotheses from them:
3. the prediction of fresh conclusions on the bases of these hypotheses and
4. testing the conclusions against further observed facts.

In common with his fellow-countrymen, Mr. Chase has great faith in semantics as a promoter of better understanding between groups. But here again he spoils his own argument when he tells us that the

American semanticist, Korzybski, predicted in 1933 that young physicists, because of the new types of communications they were beginning to use, would be the hardest, straightest thinkers the world has ever seen, and then adds that this prediction has come true. One can only assume that Mr. Chase is unacquainted with the copious writings on social and political problems which the natural scientists have been pouring out in ever-growing volume during the last five years.

All this only goes to show how much more difficult it is to apply scientific method to the behaviour of men than to that of electrons—which was not, however, Mr. Chase's purpose in writing the book.

E. M. FRIEDWALD.

Testing Radio Sets. By J. H. Reyner. (London, Chapman & Hall, 5th revised edition, 1950, pp. 215 with 15 plates and 132 illustrations, 22*s*. 6*d*.).

THE author's primary aim is to provide the fundamental principles of radio receiving set testing and to indicate the necessary logical procedure in tracing the cause of typical faults.

A considerable amount of information is provided, to the extent that more space might well have been devoted to the introduction and grouping of subject matter at the beginning of each section of the book. This would have enhanced its value as a work of reference for the laboratory worker and serviceman when dealing with particular receiver defects not amenable to ready localisation.

However, in its present form, this work should be a useful elementary manual to those who study and construct radio receiving equipment.

A. A. ROWLANDS.

The Study of Geography. By J. M. Mogey. (Volume 214, Home University Library, Geoffrey Cumberlege, Oxford University Press; pp. 164, figs. 18, 5*s*.)

IN this book, the latest addition to the Home University Library series, Dr. Mogey interprets the control of environmental factors upon the development and complexities of our modern world and civilisations. The introductory chapter on the cartographer's art, and the modern concept of geography is followed by analysis of the forces etching man's environment, and the way in which different societies live, or merely exist in the world.

After dealing briefly, but effectively, with the essential formalities of relief, climate, soils and vegetation the author proceeds to develop the main thesis of man and environment. The lives of primitive peoples, slowly dying out in the inhospitable corners of the world, the growth of societies, each specially adapted to their surroundings, is clearly portrayed. The choice of Lancashire as an example of a highly organised industrial community is ideal. Skilful analysis of the factors which contributed to the location of so many major industries in a comparatively small area, the exploitation of mineral wealth, and man's extension of his environment illustrates the complexity of our national life. In discussing the influence of geography upon politics, the author surveys the present political systems in the world, and attributes the expansion of the Soviets to geographical controls.

For the general reader this book contains a wealth of information, it stimulates and encourages thought not only upon our national problems, but enables the reader to understand more fully international affairs, and to appreciate more accurately the outlook of others. It is strongly recommended to the student of geography and allied sciences. The book is extremely well written and illustrated and is not without humour; the reader will find that the hallmark of bourgeois respectability, the bowler hat, was introduced to western society from the steppes of the Kazan.

F. A. HENSON.

Chambers's Shorter Six Figure Mathematical Tables. By L. J. Comrie. (W. & R. Chambers, London & Edinburgh, 1950, pp. 387, 12*s*. 6*d*.)

THIS abbreviated version of the already famous Chambers's Six Figure Mathematical Tables will receive a wide welcome. The many users of Mr. Comrie's other tables will expect a high standard, and will not be disappointed. In fact, Mr. Comrie is sufficiently confident of the accuracy of these tables that he considers the four or five known cases in which there is an error greater than +0·5 in the last decimal to be valuable as a trap for would-be plagiarists! The volume can be strongly recommended for general use.

Far and Near

Uranium from Gold Mines

URANIUM from South African gold mines, which constitute one of the world's biggest known sources, is being made available to the British and American governments. This represents the culmination of several years of intensive research and development, in which all three countries have taken part, on the problem of making recovery of uranium from South African gold ores an economic proposition. Although there is not a large percentage of uranium in this ore, so much is mined, that the total amount available will be relatively large, and the operation becomes economically possible because the gold 'tailings' are in most cases a waste product.

The Johannesburg negotiations were between representatives of the South African Atomic Energy Board, which includes leading members of the gold mining industry, and representatives of the United Kingdom and United States. Preliminary discussions were held in the same city a year ago.

Design and construction of the necessary plant are proceeding as a matter of urgency. Owing to security considerations, information on certain parts of the programme cannot be made public.

Getting Science Films Past Currency Barriers

THE United Kingdom is taking part in an international Film Coupon Scheme designed to overcome currency barriers preventing the free circulation of educational and scientific films. Twenty-four countries have joined in the project so far.

The scheme is organised by Unesco. Coupons are marketed in this country by the British Film Institute, 164, Shaftesbury Avenue, London, W.C.2, who will also be the central body through whom all imports and exports under the scheme will be channelled.

In this way purchasers who have been unable to obtain educational, scientific and cultural films from hard currency countries will be enabled to do so, and in the same way the United Kingdom will be able to export such films to countries which have hitherto had insufficient sterling resources.

Intending purchasers must make sure of the availability and price of the film. They should then apply to the Institute for the necessary import form which when completed should be returned to the Institute. It will then be the Institute's function to obtain the film, clear it through customs, and hand it over to the purchaser.

The Versatility of ACTH

A CONFERENCE on ACTH was held in Chicago at the end of 1950. Striking evidence was given about the efficiency of ACTH in connexion with the treatment of burns; a typical case that was described involved a three-year-old boy with 50% of his body covered by third-degree burns; he had been irrational with a fever of 103–106° for five days when ACTH was administered—to reduce the fever within a few hours and eliminate the pain. That the hormone was responsible was proved by the fact that the symptoms returned when ACTH was withheld. ACTH also promotes the growth of grafted skin, vital for the treatment of severe burns.

A paper by a research group from Cornell University told of the striking stimulus the hormone gives to premature babies. There was a remarkable increase in their vigour, as evidenced by the strength of their crying, and they developed voracious appetites, the report stated.

It was also reported that a single injection of ACTH completely and quickly

counteracts the poison of the black widow spider and the deadly copperhead snake.

Plutonium in Nature

THE separation of plutonium in millionth-gramme quantities from concentrates of Belgian Congo pitchblende is recorded in a report issued by the United States Atomic Energy Commission. Plutonium, prepared on a considerable scale in atomic piles, has thus been added to the list of natural chemical elements which have been chemically separated. The detection of the presence of plutonium in natural minerals was reported in DISCOVERY as long ago as October, 1946.

Electrons Sterilise Foods

ELECTRONICALLY TREATED foods have been found fresh and appetising after as much as four years' storage without refrigeration, it was announced in a report presented at the American Chemical Society's 118th national meeting. High-speed electrons can also sterilise drugs and produce effective vaccines. The electronic bombardment, fired in bursts lasting only one millionth of a second, sterilises meat, fish, vegetables, fruits, and dairy products without destroying their enzymes. The technique depends on a machine called a capacitron, a self-contained unit with a high enough output of elections to make it applicable to industrial processing.

A highly potent rabies vaccine has been produced using this electronic radiation, which destroys bacteria and viruses without harming the so-called antigens, the effective agents in the vaccine.

Preliminary experiments on this method of sterilisation are being made by Britain's D.S.I.R. laboratory specialising in technology.

News of Prof. Bernal

THE Soviet Government has started a system of 'Peace Prizes' which will be the Russian equivalent of the Nobel Prizes, and PROF. J. D. BERNAL has been made a member of the committee which will award the prizes.

World's Biggest Cyclotron

ENGINEERS in Sydney have begun machining giant steel slabs for the 1400-ton magnet that will control Australia's first cyclotron. This will occupy the basement of the School of Physical Sciences at the National University to be set up in Canberra. Most of the machinery for the cyclotron will be made in Australia; the rest will be imported from England.

The Canberra cyclotron will be the largest in the world, and its construction and installation will be supervised by Australian-born Professor M. L. Oliphant.

College of Food Technology

A NATIONAL College of Food Technology is to be established in London this year.

Attendance will be on a full-time basis. The college will at first be housed within the premises of the Smithfield Technical College and some nearby premises which have been adapted. Plans, however, are being made to acquire new premises soon.

Awards for Horticultural Science

THE highest award of the Royal Horticultural Society is the Victoria Medal of Honour, and the latest honours list of the Society contains four such awards. One goes to Mr. W. J. C. LAWRENCE of the John Innes Horticultural Institution, the originator of the famous John Innes composts. He is also an expert on glasshouses, and a new edition of his book *Science and the Glasshouse* has just been published by Oliver and Boyd (Edinburgh, 175 pp., 15*s*.).

Another V.M.H. has been awarded to Mr. Guy L. Wilson for his creation of new varieties of daffodils.

An M.B.E. in the New Year Honours List went to George Russell, the 93-year-old plant breeder, for his life's work—the production of the remarkable bi-colour lupins, universally known as 'Russell Lupins', which are scientifically interesting since more than one lupin species seems to have gone into their breeding.

Science Masters' Jubilee

THE Science Masters' Association celebrated its golden jubilee in January with a meeting at the Royal College of Science, and a dinner at the Coventry Street Corner House. On January 2 the Lord Mayor attended a civic reception at the Mansion House.

The S.M.A. was founded in 1900, its original title being "The Association of Public School Science Masters". It was in 1919 that the Association extended its membership to include science masters in secondary schools. Membership then was between 350 and 400 representing some 150 schools; the membership to-day is 1792.

The Association's journal has a circulation of over 7000.

Soviet Science Prizes

THE political influence in Russian Science is reflected in the list of prizes awarded by the U.S.S.R. Academy of Science "to authors of the most important scientific researches accomplished in 1950." A Mechnikov Prize, for example, has been awarded to Academicians Alexander Oparin and Mark Mitin, Corresponding Member of the U.S.S.R. Academy of Sciences Artavazda Avakyan, Professors Nikolai Nuzhdin, Noraira Sysakyan and others, for their book *Against Reactionary Morganism and Mendelism*. Another Mechnikov Prize has also been awarded to Professor Mikhail Voino-Yesenetsky of Lvov University for his work *Pathological Anatomy and Some Questions on the Pathogenesis of Malaria*. The Dokuchayev prize goes to the authors of a book entitled *The Grey Earth of Central Asia*.

Zoo's Science Director

DR. EDWARD HINDLE'S successor as Scientific Director of the London Zoo is to be Dr. L. Harrison Mathews, who will take up his position on May 1, 1951. Dr. Mathews is a Frank Smart Prizeman and Vintner Exhibitioner of King's College, Cambridge, and has travelled widely in South America, Africa and many other parts of the world on zoological research. He was at one time on the Scientific staff of the "Discovery" Committee. Dr. Mathews is on the council of the Zoological Society as a Vice-President and on the council of the Maine Biological Association.

Night Sky in February

The Moon.—New moon occurs on Feb. 6d 07h 54m, U.T., and full moon on Feb. 21d 21h 12m. The following conjunctions with the moon take place:

February

4d 15h	Mercury in conjunction with the moon			
7d 22h	Venus	,,	Venus 4°	N.
8d 05h	Jupiter	,,	Jupiter 0·6°	S.
8d 06h	Mars	,,	Mars 0·5°	S.
24d 03h	Saturn	,,	Saturn 0·4°	S.

In addition to these conjunctions with the moon, Mars is in conjunction with Jupiter on Feb. 7d 19h, Mars 0·2° N., Venus is in conjunction with Jupiter on Feb. 11d 15h, Venus 0·4° S., and Venus in conjunction with Mars on Feb. 16d 04h, Venus 0·6° S.

The Planets.—Mercury rises an hour before the sun on Feb. 1 and can be seen in the morning hours for a short time before sunrise, but later the planet draws too close to the sun for favourable observation. Venus is an evening star, setting more than two hours after the sun throughout most of the month, stellar magnitude -3·3. Mars also sets about two hours after sunset throughout most of February. Notice during the evening of Feb. 7 that Jupiter and Mars are very close together; the planets set before their conjunction can be observed in the latitude of Greenwich. Saturn rises at 21h 20m, 20h 30m and 19h 30m on Feb. 1, 14 and 28, respectively, and can be seen throughout the night in the constellation of Virgo, in the early part of the month close to η Virginis and at the end of the month about half-way between η and β Virginis.

Those who are in possession of a 3-inch telescope or one larger might like to try it on γ Virginis, a double star lying about as far east of η as η is east of β.

A stamped addressed envelope should accompany unsolicited articles sent to the Editor; otherwise no responsibility for their return can be accepted. Inquiries from readers seeking information on matters other than normal business matters must also be accompanied by a stamped addressed envelope. (Overseas readers should enclose an international postal reply coupon to cover return postage.)

Its companion is rather close but should not be difficult to see unless the conditions are bad. The very bright star Spica (α Virginis) can be seen to the south-east of the other stars referred to and is also a double star, but whose companion is too near to be distinguished. The two stars are only about 6 million miles apart; each revolves around the common centre of gravity of the system in about 4 days. It may be pointed out that the earth and the moon also revolve around their common centre of gravity or *barycentre* in a little over 27¼ days; this point is about 1000 miles below the earth's surface. Many people make the mistake of thinking that the moon revolves around the earth's centre, but actually in all cases of such revolutions of two connected bodies, the revolution takes place around their common centre of gravity.

A Television "University"

A PHILADELPHIA television station has started courses of adult education in co-operation with nineteen local colleges and universities. Televised lectures lasting 15–30 minutes will be given on such subjects as "The Electrical Nature of Matter."

Careers in Chemical Engineering and Biology

THE emphasis on technology as the key to improving Britain's economic position has led to reviews (organised by the Technical Personnel Committee of the Ministry of Labour) of supply and demand of men trained in special fields. These reviews are published by H.M. Stationery Office as sixpenny pamphlets; those on physics, geology and chemistry were mentioned in our September 1950 number (p. 299). A new pamphlet in this series deals with the situation for chemical engineers. It appears that the output of professionally qualified men will fall short of requirements by at least 15% for the next five years, so any university graduate in chemical engineering, even with a pass degree, is assured of being snapped up by industry or a Government department.

How do chemical engineers make themselves as scarce as compositors, without working to rule or limiting the number of entrants? The courses of training are arduous, with a three-year post-intermediate degree course the easiest. Otherwise, it is necessary to obtain a post-graduate diploma following a degree in chemistry or mechanical engineering or to take the examination of the Institution of Chemical Engineers. Neither way is easy, for the student must know how to use more physical chemistry than a chemist, and more fluid dynamics and heat transfer than a mechanical engineer. If he is prepared to do this, he can expect for the whole of his professional career to earn about 50% more than they do.

This position may not last forever but is the aftermath of a period when chemical engineers were not particularly valued in Britain. Their great field is in chemical industry and oil refining. Up till now, the British chemical industry has relied on teams of chemists and engineers instead of chemical engineers, and the home oil refineries are only now being built. But with a change of policy now taking place, the prospects for chemical engineering are bright. The development of the subject in the country of its birth has been hampered too long by theory that chemical engineering problems are best solved by chemists plus engineers. It can stand in its own right and competition with the old method should demonstrate an inverse Gresham's Law, the better currency driving out the worse.

Another new report sums up the balance as between supply and demand of biologists. This states that before the war about 260 biologists graduated each year, and that by 1948 the output was more than twice that figure. The demand, however, has not expanded to the same extent. For the period 1950–54 the estimated supply (of over 3400 graduates) is likely to exceed the demand by about a thousand. The report comes to the following conclusion: "It would seem right that prospective biology students should be informed that biology is a science in which it will become relatively difficult, rather than the reverse, to secure employment appropriate to the qualifications obtained." Doubtless many who read this report will ask whether Britain makes the maximum use of biologists, and there would seem to be a case for an investigation of this question by the biological profession.

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